A HYDROGEOLOGICAL INVESTIGATION OF THE CLOSED NORWICH WASTE DISPOSAL AREA IN NORWICH, ONTARIO

FEBRUARY 1990

Ontario
Environment
Environnement
Jim Bradley, Minister/ministre

ISBN 0-7729-4770-8

A HYDROGEOLOGICAL INVESTIGATION
OF THE CLOSED
NORWICH WASTE DISPOSAL AREA
IN NORWICH, ONTARIO
(No. 070701)

Report Prepared for:
Waste Management Branch

Report prepared by:
R. Blackport
B. Boyle

FEBRUARY 1990

RECYCLABLE

DISCLAIMER

This report was prepared for the Ontario Ministry of the Environment as part of a ministry-funded project. The views and ideas expressed in this report are those of the author and do not necessarily reflect the views and policies of the Ministry of the Environment, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

0.0 EXECUTIVE SUMMARY

A hydrogeological investigation of the closed Norwich Waste Disposal site in Norwich, Ontario was undertaken by Terraqua Investigations Ltd., for the Ontario Ministry of the Environment, in the Summer and Fall of 1988. The purpose of the study was to provide information with respect to the presence of, or potential for, impact by the landfill on human health and safety or the environment.

The investigation was comprised of: 1) a preliminary literature review, during which available information regarding the history, geology and hydrogeology of the site were examined; 2) a field program, during which 10 monitoring wells were installed, water levels were measured, overburden hydraulic conductivity was tested, and water samples were collected and analysed; 3) data synthesis, which involved the compilation and analysis of all available relevant data; and 4) preparation of suitable conclusions and recommendations with respect to the status and future of the landfill.

It was found that the waste disposal area, which is situated to the north of, and bounded on three sides by, Otter Creek, is underlain by approximately 2 to 4 metres of moderately permeable (10^{-5} to 10^{-6} m/s) layered sand and gravel, which appears to be continuous across the site. Beneath this unit, an interval (at least 6 metres in thickness) of lower permeability (10^{-8} m/s) dense grey stony sandy silt till was encountered. The northern limit of the waste/fill butts up against a sequence of layered

silty fine sand, clay and silt, approximately 5 to 6 metres in thickness. The southern limit of waste/fill disposal is delineated by a 2 to 3 metre high steep slope which faces Otter Creek.

The maximum thickness of waste penetrated was 5 metres, in the centre of the landfilling area. The major components of the waste, based on visual observation during the drilling program and the site visits, are: asphalt, domestic refuse, plastic, metal, fabric, wire fencing, paper, bricks, and charred wood and branches. A significant quantity of silty sandy soil had been combined with the waste, and a sparsely vegetated, 0.4 to 0.7 metre thick cap of a similar material was present at ground surface. Township Officials had indicated that the majority of the garbage had been disposed of in the eastern half of the site, while the remainder had been covered with relatively clean fill, comprised of charred wood and branches, soil, rocks, boulders, and blocks of concrete. No evidence of any deposition of industrial or potentially hazardous waste was observed during the course of the field work and site visits.

Generally, groundwater was observed to flow from west to east across the site, with an average horizontal hydraulic gradient of about 0.01. The water table is relatively flat across the site but is higher on the west edge where the till is elevated. The main component of flow is horizontal, though slight downward gradients existed at two monitoring locations. The water table was located below the waste during much of the study period,

which would tend to limit the quantity of leachate generated. No leachate seeps or obvious surface water pathways were observed on the waste disposal area.

Typically, water derived from the landfill is elevated in alkalinity, hardness, ammonia, nitrogen, DOC, manganese, sodium, chloride, sulphate, calcium and magnesium. Alkalinity, hardness, organic nitrogen, DOC, manganese and sodium are present in excess of the MOE drinking water criteria directly beneath the landfill, while only manganese and sodium are in excess of desirable limits at each of the remaining landfill monitors. Although this water is not used for drinking purposes, the Drinking Water Quality Objectives have been used as a means of comparing the water quality to a known standard.

There is no evidence of impact on Otter Creek as a result of leachate seepage from the waste disposal area. Of the above-mentioned parameters which were found to be elevated in the leachate, only DOC was present in excess of the maximum desirable concentration in the creek samples. However, the water samples obtained from both upstream and downstream locations in the creek contained levels of nitrate and organic nitrogen which were greater than three times higher than those found at each of the other monitoring locations, which indicates that the landfill is not the source of this contamination. The creek water is not used for domestic consumption, but is commonly used for irrigation and cattle watering.

No potentially explosive gases were detectable in the open air

surrounding the landfill. However, detectable concentrations of gas were observed in three monitoring wells located within the waste/fill; gas was present in excess of the lower explosive limit at the centre of the landfill, while trace levels were detected at two monitors on the edge of the waste.

It was concluded that the waste disposal area at Norwich does not, at present, (nor is it likely to in the future) adversely affect the water quality of Otter Creek. In addition, the landfill is not likely to pose a threat to the quality of water derived from nearby domestic or municipal wells.

The concentration of methane (landfill gas) within the landfill, however, may pose a risk to human health and safety if any development of the landfill were to take place.

1.0 INTRODUCTION

On May 26, 1988, Terraqua Investigations Ltd. (Terraqua) was awarded a contract by the Waste Management Branch of the Ministry of the Environment (MOE) to conduct a hydrogeological assessment of the closed Norwich Waste Disposal Site (No. 070701) in Norwich, Ontario. This study is one of several which are presently being carried out across Ontario, as part of the MOE's "Assessment of Closed Waste Disposal Sites - Phase III Investigation and Monitoring."

Phase III of the assessment program follows 1), the creation of an inventory of active and closed waste disposal sites in the Province of Ontario, and 2), a preliminary investigation in which the sites were classified and study priorities were established. The selection of the Norwich Landfill was based on the paucity of available information regarding the site, and its proximity to Otter Creek.

The purpose of Phase III is to define any impacts or risks that the site may pose to human health and safety or the environment, and to determine whether or not a detailed investigation of remedial options is required during Phase IV of the program.

The objectives of the study are as follows:

1) to define any existing or potential impacts on Otter Creek;
2) to define any existing or potential impacts on the Norwich Municipal water supply well, or other local

water wells;

3) to define the site's leachate characteristics;

4) to define the nature and extent of any landfill-related gas hazards;

5) to define the site's present physical condition (i.e., site boundaries, areal extent of waste disposal, engineering works, age, etc.);

and 6) to develop recommendations that will lead to any necessary improvement of site conditions, including:

a) a site monitoring program,

b) remedial actions,

c) the necessity of a Phase IV investigation of remedial options.

The following report includes the results of the preliminary site assessment, a detailed study methodology, the results of the drilling and monitoring programs, and appropriate conclusions and recommendations regarding the status and future of the landfill.

2.0 STUDY METHODOLOGY

2.1 PRELIMINARY ASSESSMENT

An initial visit was made to the Norwich waste disposal site during the preparation of the proposal (October, 1987) in order to observe the topography and physiography in the vicinity of the landfill, and to examine the landfill itself for any evidence of leachate seeps, surface water ponding, affected vegetation, etc. Township officials were interviewed with respect to the history of the site at this time. Additional visits to the waste disposal area were made in July 1988, for the purpose of assessing drilling conditions, designating borehole locations, and clearing underground services.

A review of available relevant literature was conducted in order to obtain background information regarding the site, and in order to assess the groundwater and surface water use within 2 kilometres of the landfill. Maps pertaining to overburden geology, drift thickness, and bedrock geology were examined, as were local MOE water well records. A study by Sibul (1969) of the water resources of the Big Otter Creek Drainage Basin was also reviewed. The Certificate of Approval for the disposal of domestic waste, and available air photos, were also examined during the course of the study.

2.1.1 Site Location

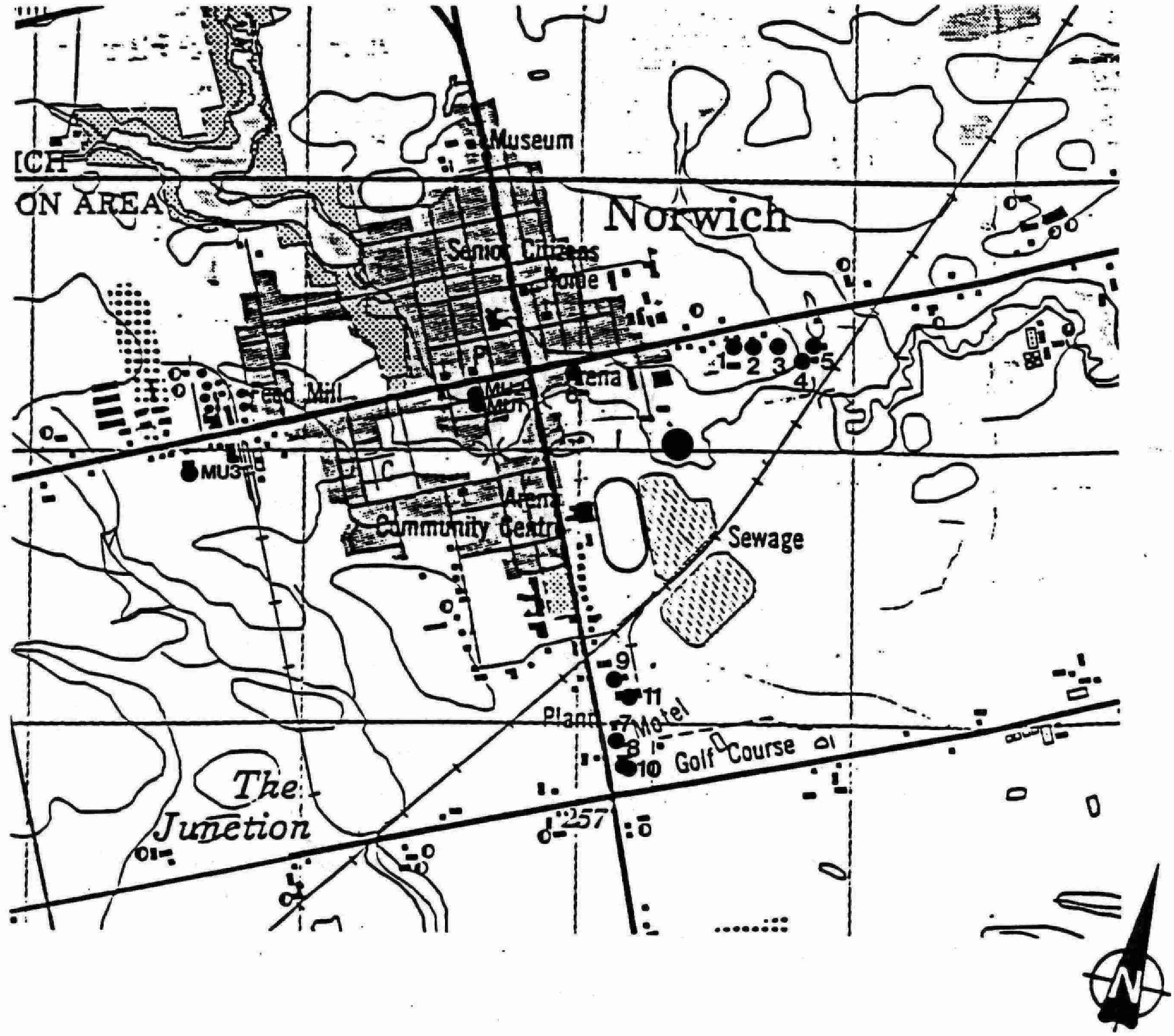
The Norwich waste disposal site is located at the south end of

Phoebe Street, in the southeastern quadrant of the Village of Norwich, on Lot 7, Concession 5, Norwich Township, Oxford County (Figure 1). Otter Creek flows past the western and southern boundaries of the site (in a generally west-east direction) approximately 30 to 45 metres from the edge of the landfill. A municipal sewage lagoon, having a surface area of about 6 hectares, is located 100 metres south (and upgradient) of Otter Creek (Figure 2). A septic field bed which services the Norwich Curling Rink is situated to the northwest of the landfill. A small parcel of land south of the fence near OW4 (Figure 3) was sold to the Holland Hitch Company by the Township of Norwich. This property is not being used by Holland Hitch at present.

The southern, eastern and western limits of the waste/fill are quite distinct: a steep slope approximately 2 to 3 metres in height delineates the area used for landfilling. The northern limit, however, could not be determined prior to the commencement of the field program, as the refuse had been graded to conform with the adjacent topography.

2.1.2 Site History

The Norwich Landfill was officially licensed in 1974 (Certificate of Approval No. 070701) to receive domestic and commercial waste; however, residents of the Village of Norwich have indicated that the site was considered an "open" dumping ground for several years prior to this. According to the present Clerk for the Village of Norwich, the waste disposal area was not regularly



Scale 1:25000

Legend

● Site

1● Water Well Number (See Table 1.)

MU● Municipal Well

FIGURE 1 LOCATION OF SITE

NORWICH LANDFILL

PROJECT TA 8879

CLIENT: Ministry of the Environment

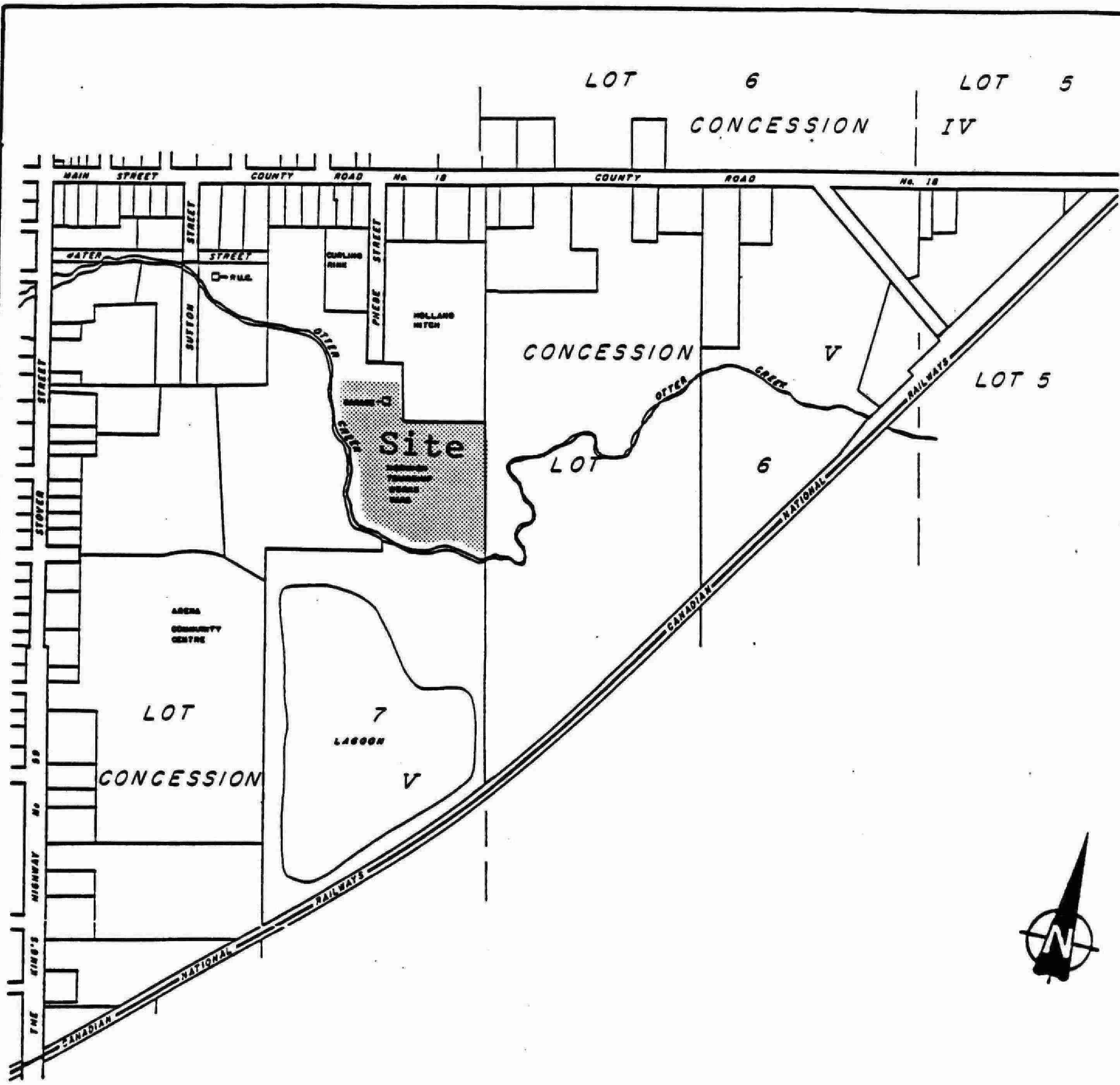


FIGURE 2 SITE SURROUNDINGS

NORWICH LANDFILL

PROJECT TA 8879

CLIENT: Ministry of the Environment

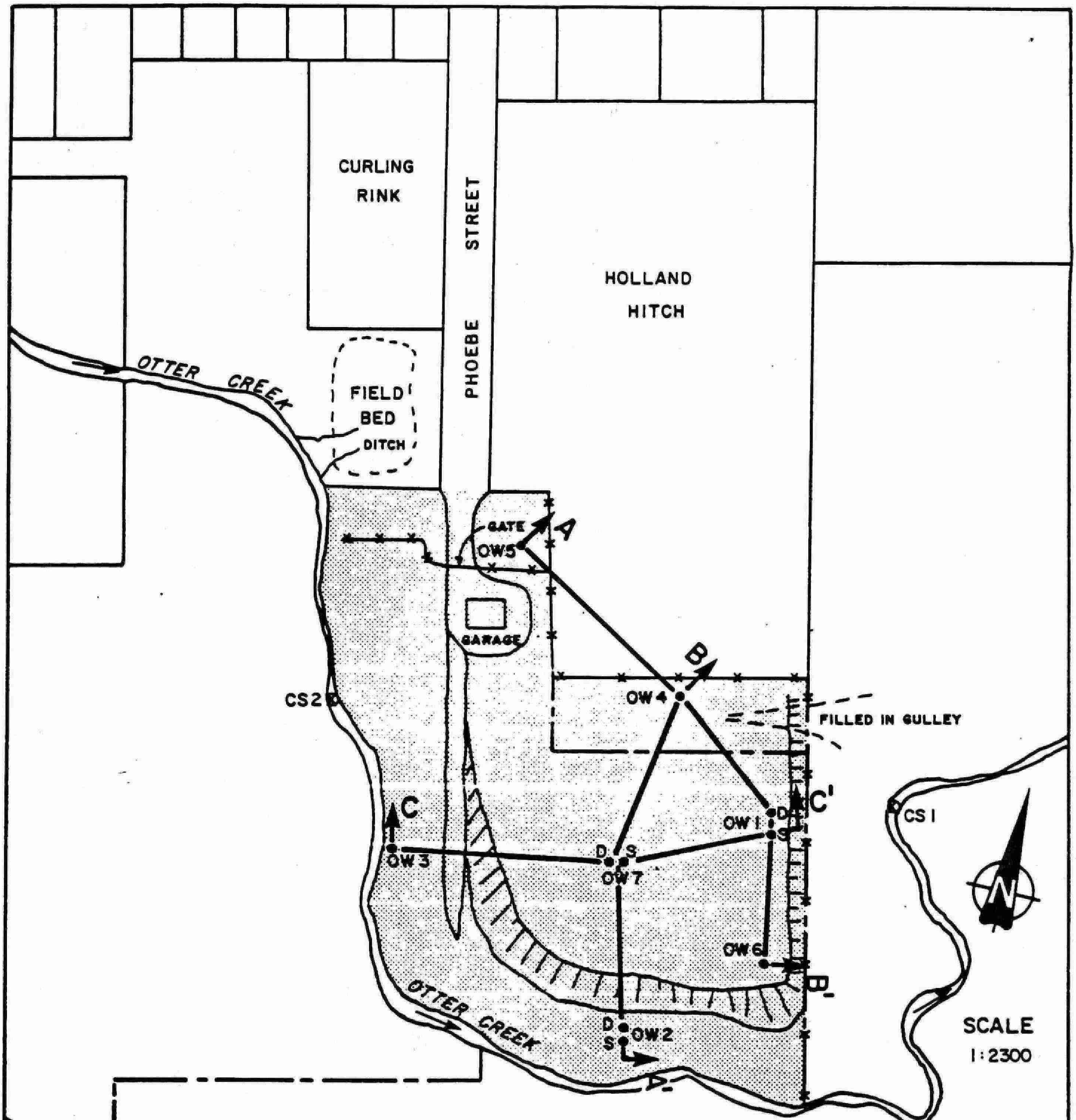


FIGURE 3
SITE PLAN
NORWICH LANDFILL
PROJECT TA 8879
CLIENT: Ministry of the Environment

LEGEND

• OW 1	MONITORING WELL NUMBER
D; S	DEEP; SHALLOW (NESTED MONITORS)
	STUDY AREA
⊗-CS1	CREEK SAMPLE LOCATION
A—A	CROSS SECTION LOCATION

staffed, nor did an office exist on-site. The landfill was officially closed in 1976.

During the operating life of the landfill, the Village apparently contracted personnel to collect refuse, and the Norwich Township Roads Department contracted front-end loaders and graders for the purpose of levelling the waste.

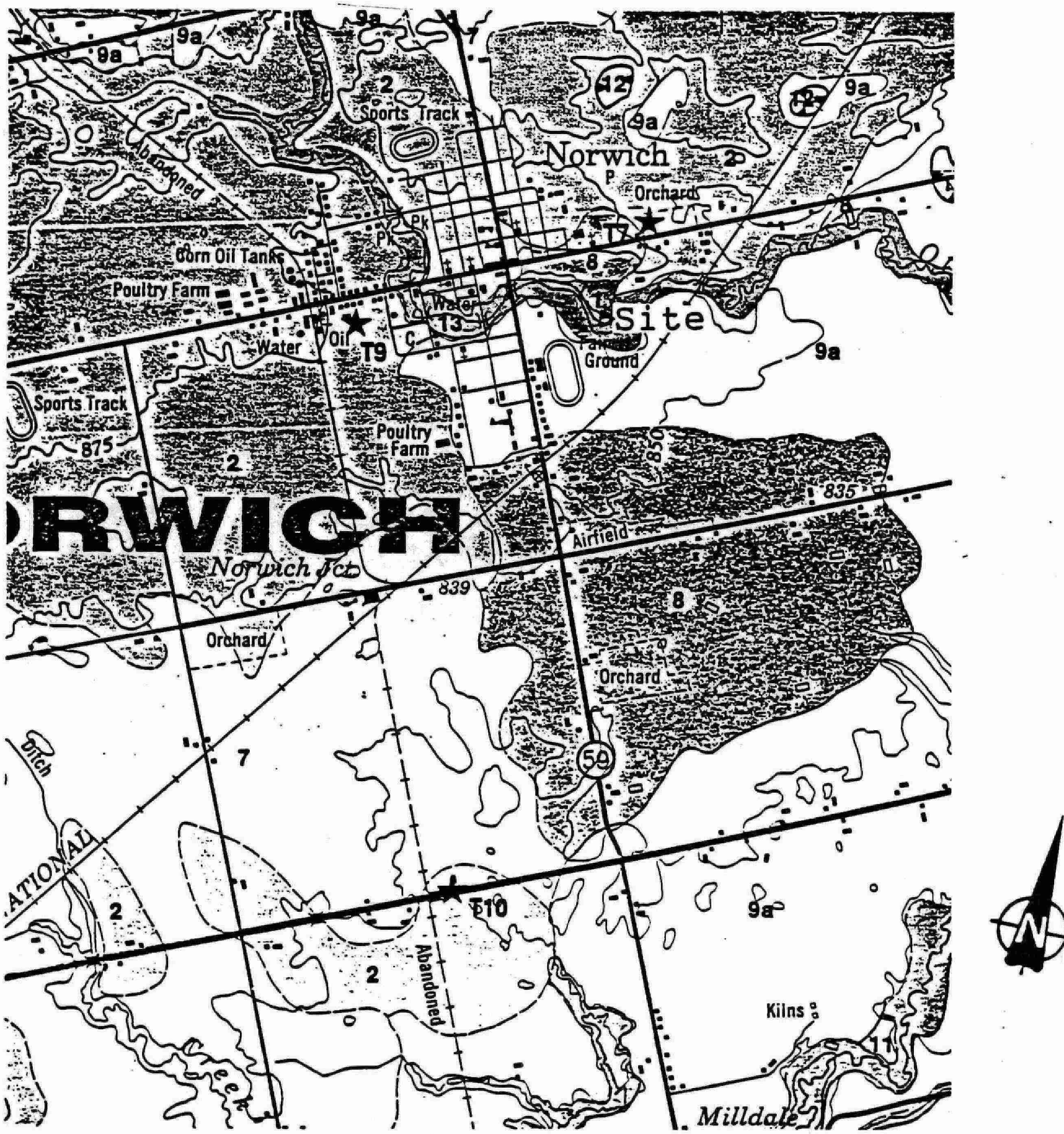
There is evidence of recent disposal of charred wood, brush, concrete and soil along the southwestern face of the landfill, and the Township presently uses the site for the storage of topsoil, concrete and pipe for the Roads Department.

At present there are no engineering works in operation on site. A buried cable owned by the Norwich Telephone Company runs along the west edge of the service road on the west side of the waste disposal area.

2.1.3 Regional Geology

Mapping of the Quaternary geology by Barnett (1982) indicates that the Catfish Creek Till, a stony sandy silt till, underlies the landfill. The site is apparently bounded by glaciolacustrine deepwater deposits (massive to laminated silt, minor clay) to the north, and by modern alluvial deposits (clay, silt, sand and muck) to the south and west (Figure 4).

The alluvial deposits are generally present on both sides of Otter Creek in bands approximately 100 to 200 metres wide. The extensive Norfolk sand plain, a level to gently rolling abandoned



QUATERNARY

RECENT

14 Cultural features deposits: earth fill.

13 Modern alluvium: clay, silt, sand, muck.

12 Bog deposits: muck, peat or marl.

PLEISTOCENE

LATE WISCONSINAN

11 Older alluvium in terrace remnants: fine to medium sand with occasional pebbles.

10 Glaciolacustrine beach or bar deposits: gravel to gravelly coarse sand.

9 Glaciolacustrine shallow water and deltaic deposits slightly modified by wind.
9a Fine to medium sand.
9b Sand containing occasional pebbles.

8 Glaciolacustrine deepwater deposits: massive to laminated silt, minor clay.

7 Glaciolacustrine deepwater deposits: massive to laminated clay, minor silt.

6 Glaciofluvial outwash and deltaic deposits: gravel and gravelly sand.

5 Glaciofluvial outwash and deltaic deposits: sand.

4 Glaciofluvial ice-contact stratified drift: morainic or kame sand and gravelly sand.

3 WENTWORTH TILL: silt till.

2 PORT STANLEY TILL: silt to silty clay till.

1 CATFISH CREEK TILL: stony sandy silt till.

FIGURE 4 QUATERNARY GEOLOGY

NORWICH LANDFILL

PROJECT TA 8879

CLIENT: Ministry of the Environment

0 1000

metres

Barnett, P.J. and Girard, C.K.
1982 Quaternary Geology of the Tillsonburg Area; Ontario Geological Survey, Map 2473 Quaternary Geology Series, scale 1:50 000. Geology 1976.

lake plain composed of fine to medium sand, is exposed at surface, directly to the south of Otter Creek. The municipal sewage lagoon has apparently been constructed within this unit.

The total drift thickness in the vicinity of the landfill is expected to be on the order of 30 metres.

The Amherstburg Formation of the Detroit River Group subcrops beneath the Norwich Landfill site. It is comprised of grey to dark brown limestone and dolomite which is locally cherty and bituminous (Barnett, 1982). No bedrock outcrops have been noted in the Otter Creek/Big Otter Creek drainage basin (Sibul, 1969).

2.1.4 Hydrogeology

Otter Creek flows to the west and south of the landfill site, and enters Big Otter Creek approximately five kilometres southeast of Norwich. Otter Creek drains the relatively flat, undulating till and sand plains that make up the northern part of the Big Otter Creek drainage basin.

The topographic maps reviewed indicate that groundwater probably flows in an easterly direction across the landfill, with some components to the south and southeast towards Otter Creek.

No obvious surface water pathways, such rills or rivulets, were observed on the landfill surface during the visit. Nor were any seeps or evidence of seeps (such as affected vegetation) observed during the site visits and field work.

2.1.5 Assessment of Groundwater and Surface Water Usage

Generally, all wells in and around the Village of Norwich have been installed in the overburden (Table 1); however, there are no wells downgradient of the waste disposal area (Figure 1). Those upgradient of the landfill are primarily located in the confined gravel aquifer which is located at an elevation of approximately 247 metres (Table 1). Groundwater is mainly used for domestic consumption, farming operations, irrigation and municipal supplies. Three municipal wells are located within or near the Village of Norwich. Wells MU1 and MU2 (Figure 1) are situated approximately 750 metres to the west of the site, at depths of 33 metres and 33.8 metres respectively. A third well, MU3, is located about 1.8 kilometres to the west of the landfill, and is 42 metres in depth. All three of these wells are located within the bedrock and are considered to be upgradient of the waste disposal area.

A reservoir/conservation area (i.e. a dammed up portion of Otter Creek) to the northeast of Norwich (Figure 1), is primarily used for recreational purposes. Several irrigation ponds are located on or near the banks of Otter Creek to the east of the site.

2.2 DRILLING AND SOIL SAMPLING

A total of seven drilling locations (three of which were to have nested monitors) were selected at the Norwich Landfill site (Figure 3). A CME track-mounted rig was required to drill at the two drilling locations near Otter Creek, as the ground surface

OXFORD COUNTY

	MUNICIPALITY CONCESSION ETC	LOT	WELL NO	UTM EASTING NORTHING	ELEV FEET	DATE	DRILLER	CSG DIA INS	KIND OF WATER	WATER FOUND FEET	STAT LVL FEET	PUMP LVL FEET	TEST RATE GPM	TEST TIME HR/MN	WATER USE	OWNER/LOG/SCREEN DEPTHS IN FEET TO WHICH FORMATIONS EXTEND
	NORTH NORWICH TOWNSHIP															
1	CON 5	6	47- 1831	533550 4759400	850	05/63	5413	5	FR	71	47	55	10	2/00	DO	FILIPOVITS F YLLW CLAY BLDR 0011 GRVL 0023 GREY CLAY 0034 GRVL 0047 STNS 0072
2	CON 5	6	47- 1829	533615 4759400	850	09/60	5438	5	SU	70	45	53	10	2/00	DO	MOORE D CLAY STNS 0008 GRVL 0014 GREY CLAY 0034 GRVL 0070
3	CON 5	6	47- 1833	533725 4759400	850	06/66	5413	5	FR	48	28		5		DO	DEHE W CLAY BLDR 0018 GREY CLAY STNS 0024 GRVL 0045 CSND 0048 (S 0045 03)
4	CON 5	6	47- 1830	533800 4759350	850	07/61	2601	5	FR	60	25	35	3	24/00	DO	MOORE J CLAY 0020 STNS CLAY 0055 MSND GRVL 0060
5	CON 5	6	47- 1832	533855 4759375	850	07/64	5413	5	FR	59	32	33	10	15/00	DO	VANESCH A YLLW MSND BLDR 0025 GRVL 0050 CSND 0059 (S 0054 03)
6	CON 5	7	47- 2639	532980 4759290	850	04/68	5501	5	FR	39	19	19	12	6/00	DO	PITE STANLEY MSND 0015 CLAY 0038 GRVL 0040
7	CON 5	7	47- 4339	533120 4757920		1?/75	2519	5	FR	61	12	29	5	1/00	CO	J & J PRECAST FILL 0002 BRWN CLAY SNDY 0017 GREY CLAY SAND LYRD 0056 GREY SAND 0061 BRWN GRVL 0063
8	CON 5	7	47- 1837	533150 4757850	840	10/65	2519	30		DRY						AEROSS LTD CLAY MSND 0005 BLUE CLAY 0020 STNS 0021
9	CON 5	7	47- 1835	533150 4758150	845	05/63	3511	6	FR	59	20	26	8	4/00	ST	POLLARDS DAIRY BRWN CLAY 0010 BLUE CLAY 0030 GRVL 0059
10	CON 5	7	47- 1836	533155 4757840	840	10/65	2519	30	FR	33	30		1		DO	AEROSS LTD CLAY MSND 0005 BLUE CLAY 0030 GREY CLAY 0033 GRVL 0036
11	CON 5	7	47- 1834	533175 4758100	845	03/56	3540	7	FR	58	18	25	8	2/00	IN	PILLARD BROTHERS BRWN CLAY 0010 BLUE CLAY 0030 MSND GRVL 0050 GRVL 0058

TABLE 1. LOCAL MOE WATER WELL RECORDS

was found to be extremely irregular. A truck-mount rig was used at the remaining boreholes. Hollow stem augering, using 10.8 centimetre (4.25 inch) I.D. augers was employed, and continuous samples were obtained at one deep borehole. At all other boreholes, split-spoon samples were retrieved at appropriate intervals, depending upon the geological units encountered. The samples were logged and photographed in the field, and selected sub-samples were stored in labelled and sealed plastic bags. Four representative samples were sent to a local laboratory for grain size analysis.

The rationale for the borehole placement is described below.

Two boreholes (OW5 and OW4) were drilled at the northern limit of the waste disposal area. The purpose of OW5 was to delineate the northern extent of the waste and to determine background water quality. Borehole OW4, which is located on a parcel of land now owned by Holland Hitch, was also drilled to delineate the limit of the waste, and a shallow well screen was installed in the event that water table mounding might take place. Boreholes were drilled at two locations between Otter Creek and the landfill (OW2 and OW3) in order to assess the geology and the quality of groundwater entering the creek. Nested monitors were installed at OW2 to determine the vertical hydraulic gradient near the edge of the creek. Boreholes OW1, OW6 and OW7 were placed within the waste disposal area in order to assess the type and extent of the waste and to evaluate leachate quality. Nested monitors at OW1 and OW7 were installed for the purpose of determining vertical

gradients and hydraulic conductivity variations with depth in the overburden, and for assessing any variations in groundwater quality with depth.

2.3 MONITORING WELL INSTALLATION

Upon completion of soil sampling at each borehole location, a monitoring well was installed by placement through the hollow stem augers. Depths were chosen based on the geologic material encountered and on the location of water found during drilling. All monitors were constructed of 5 centimetre (2 inch) diameter flush-joint threaded PVC pipe; the well screens (of various lengths) were comprised of 5 centimetre diameter continuous-slot PVC.

Where the native material was granular in nature, (i.e. sand or gravel) the overburden was allowed to collapse around the well screen to form a natural filter pack. Where this was not the case, coarse silica sand (3 mm diameter) was poured into the borehole annulus to form the sand pack. Generally the sand pack extended 0.3 to 1 metre above the top of the well screen. A bentonite pellet seal, on the order of 0.5 to 1.5 metres in thickness, was placed above the sand pack in order to prevent the vertical migration of groundwater down the borehole. In the event that the seal was constructed above the water table, a layer of benseal was poured above the bentonite pellets and was moistened using distilled water. Special attention was paid to the integrity of the seals in the deep monitors at the nested

monitoring locations.

The remainder of each borehole was backfilled with auger cuttings to within 1 to 2 metres of ground surface. Protective steel casings were installed at this time, and the holes were grouted with bentonite cement for the purpose of preventing the infiltration of surface water into the borehole annulus.

2.4 WELL DEVELOPMENT

Following the completion of monitoring well construction, the static water level and total depth of each well were measured, and the volume of water within the well bore was calculated. At least four well bore volumes were pumped from each well, using a fully dedicated WaTerra pump, in order to remove fine-grained material from the filter pack and ensure that representative water samples would be collected during sampling. The pH of the groundwater was measured following the removal of each bore volume, and subsequent bore volumes were removed until the pH was observed to stabilize.

2.5 WATER LEVEL MONITORING

The static water levels in each monitoring well were measured on eight occasions between July 7 and October 1, 1988. Measurements were taken as depth below the highest point at the top of the PVC riser pipe, using a battery-operated probe with a calibrated measuring tape. The elevations of the top of the PVC monitor and ground surface at each borehole location were level

surveyed relative to a local benchmark, and static water level elevations were calculated accordingly. The survey loop was closed to ensure accuracy.

2.6 HYDRAULIC CONDUCTIVITY MEASUREMENT

The hydraulic conductivity of the overburden was determined by pumping water from the well (using dedicated WaTerra pumps) and measuring the rate of water level recovery. The Hvorslev rising-head method, which calculates the *in situ* hydraulic conductivity of the geologic material next to the sand pack, was used to analyse the recovery data.

2.7 WATER SAMPLING

Six groundwater samples and two creek water samples (upgradient and downgradient of the landfill) were obtained on August 5, 1988 (following well development) and submitted to Beak Analytical Services for analysis of general water quality parameters.

As the water table was not mounded up within the Landfill during the first phase of sampling, a leachate sample was not collected at that time. The precipitation which occurred in August and September subsequently caused the water level to rise above the base of the waste, and a leachate sample was collected on October 11, 1988, and analysed for EPA priority pollutants (624-Volatiles, and 625-Acid and Base Neutral Extractables) at Canviro Analytical Laboratories Ltd.

The groundwater and surface water samples were analysed for the parameters indicated in Table 2. The creek water was also analysed for BOD_5.

The samples were stored and preserved as indicated in Table 2. All samples which were to be analysed for metals were first field filtered using 0.45 micron filter paper, then acidified using nitric acid.

2.8 LANDFILL GAS MONITORING

The concentrations of explosive (mainly methane) gas within and around the waste disposal area were monitored using a Sniffer (Model G) Gas Probe. The probe was used to determine whether the fill contained or was likely to contain gas in concentrations in excess of 10% of the lower explosive limit (i.e. 0.47% methane), to determine the lateral extent of any methane migration, and whether or not any local development was or would be at risk. The probe was inserted into each monitoring well casing as far as possible and a representative air sample was collected by squeezing the suction bulb. The concentration of explosive gas was read from the indicator and then recorded. Ambient air quality was also tested at the boundaries and on top of the landfill.

WATER QUALITY ANALYSIS PARAMETERS

Alkalinity
Hardness
Total Kjeldahl Nitrogen
Ammonia Nitrogen
Nitrate Nitrogen
Nitrite Nitrogen
DOC
Phenols
Iron
Manganese
Sodium
Copper
Barium
Cadmium
Chromium
Lead
Fluoride
Bromide
Calcium
Magnesium
Cobalt
Nickel
Beryllium
Molybdenum
Vanadium
Aluminum
Potassium
Strontium
Zinc
Chloride
Sulphate

SAMPLE HANDLING PROCEDURES

Group	Parameter	Container	Preservation
1.	Calcium, Magnesium, Sodium Potassium	PE	4 deg. C
2.	Trace Metals	PE	filtered field, HNO_3
3.	Alkalinity	PE	4 deg. C
4.	Sulphate, Chloride	PE	4 deg. C
5.	Cyanide	Glass	NaOH, 4 deg. C
6.	Ammonium	Glass	4 deg. C
7.	COD, TOC	Glass	4 deg. C
8.	Phenols	Glass	$CuSO_4$,H_3PO_4,4 deg. C
9.	Volatiles (MISA Groups 16, 17, 18)	Glass/Teflon-lined Septa	4 deg. C
10.	Base-Neutral Extractables (MISA Groups 19 and 23)	Glass/Teflon-lined Septa	4 deg. C
11.	Acid Extractables (MISA Group 20)	Glass/Teflon-lined Septa	4 deg. C
12.	pH (field measurement) Electrical Conductance (field measurement)		

TABLE 2

3.0 RESULTS

3.1 SITE GEOLOGY

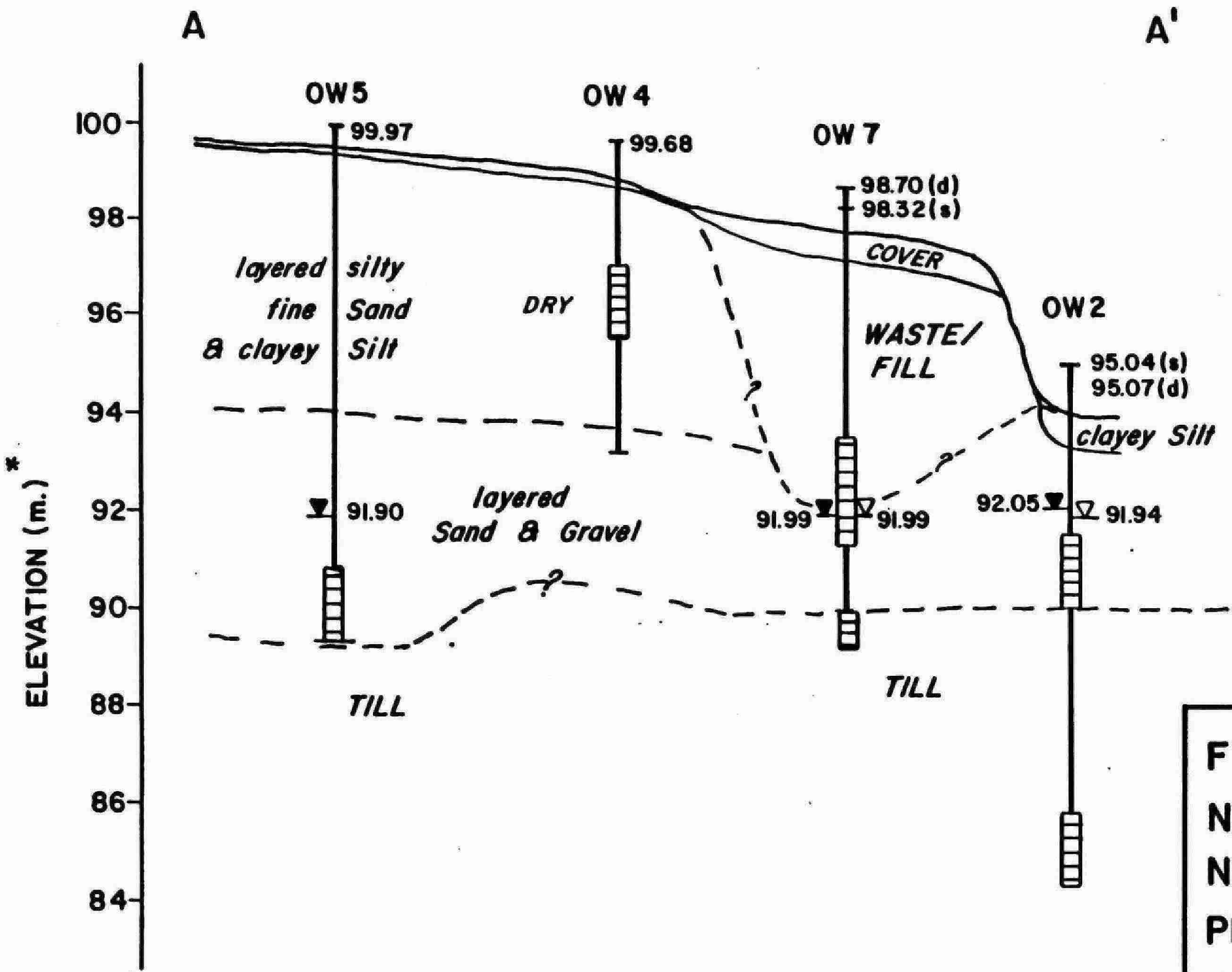
Borehole logs detailing the site geology and all monitoring well installations are presented in Appendix A, as are representative grain size analyses.

3.1.1 Geologic Profile

In general, the Norwich Landfill site is underlain by a sequence of glaciolacustrine deepwater deposits, shallow water deposits, and the Catfish Creek Till, respectively (Figures 5, 6 and 7).

Along the northern boundary of the waste disposal area, (i.e. at OW5 and OW4) approximately 5 to 6 metres of interlayed silty fine to very fine sand, silt and clay is present below ground surface (Figure 5). Beneath this unit, which is apparently of deepwater glaciolacustrine origin (Barnett, 1982). An interval of interlayered medium to coarse sand and gravel, having local cobbly and silty lenses, with a thickness of about 3 to 4 metres was encountered (Figure 6). This glaciolacustrine shallow water deposit underlies the entire site and was found at each of the drilling locations. At borehole OW3, alluvial deposits comprised mainly of layered silty clay and clayey silt were penetrated above the sand and gravel unit.

A dense, grey stony sandy silt till (Appendix A), presumed to be the Catfish Creek Till, was found beneath the layered sand and gravel at OW1, OW2, OW3, OW5 and OW7 (Figures 5 and 7). The till



*RELATIVE TO LOCAL BENCHMARK (100.0 m.)

HORIZONTAL SCALE 1:1150

FIGURE 5

N-S CROSS-SECTION A-A'

NORWICH LANDFILL

PROJECT TA 8879

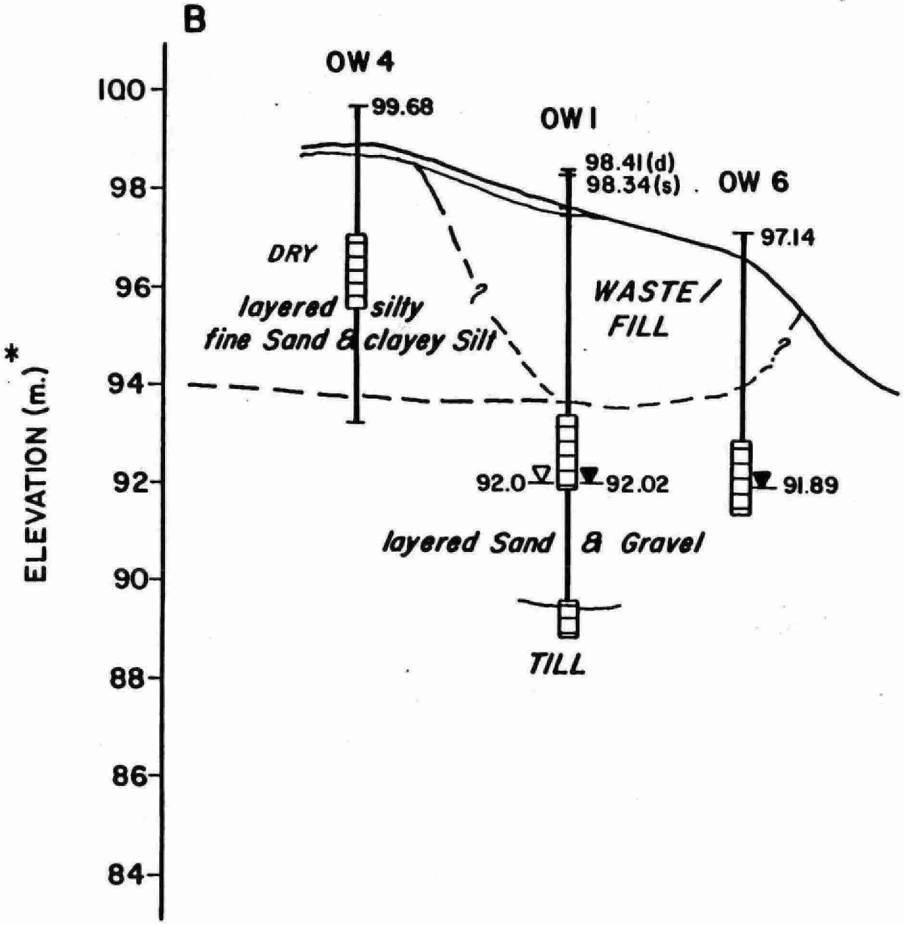
CLIENT: Ministry of the Environment

LEGEND

SCREENED INTERVAL

SHALLOW MONITOR WATER LEVEL

DEEP MONITOR WATER LEVEL
(Water Levels as of July 27, 1988)



* RELATIVE TO LOCAL BENCHMARK (100.0 m.)

HORIZONTAL SCALE 1:1150

FIGURE 6

N-S CROSS-SECTION B-B'

NORWICH LANDFILL

PROJECT TA 8879

CLIENT: Ministry of the Environment

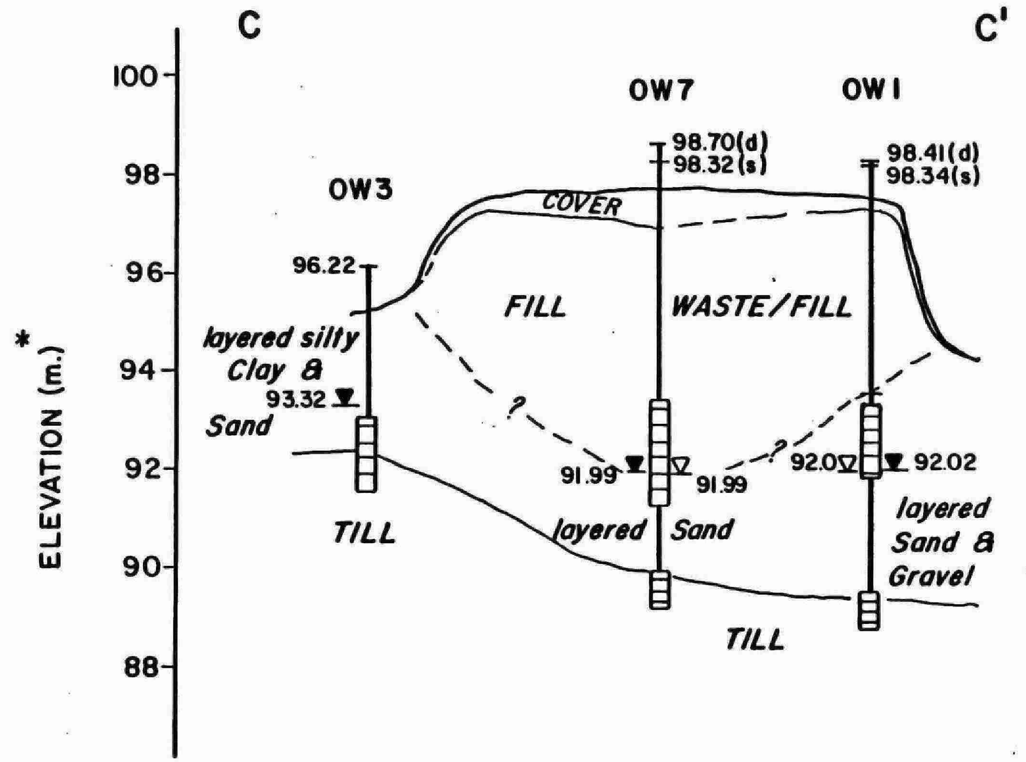
LEGEND

SCREENED INTERVAL

SHALLOW MONITOR WATER LEVEL

DEEP MONITOR WATER LEVEL

(Water Levels as of July 27, 1988)



* RELATIVE TO LOCAL BENCHMARK (100.0 m.)

HORIZONTAL SCALE 1:1150

FIGURE 7

W-E CROSS-SECTION C-C'

NORWICH LANDFILL

PROJECT TA 8879

CLIENT: Ministry of the Environment

LEGEND

SCREENED INTERVAL

SHALLOW MONITOR WATER LEVEL

DEEP MONITOR WATER LEVEL

(Water Levels as of July 27, 1988)

was quite stiff and compact at most of the above locations, with the exception of OW2, where it appeared to have been reworked.

3.1.2 Distribution of Waste

Domestic waste and/or fill was encountered at three of the monitoring locations in this study: OW1, OW6 and OW7. The greatest thickness of waste was found at OW7, where approximately 5 metres were penetrated (Figure 7).

Township of Norwich officials who were familiar with the operation of the waste disposal area indicated that the northern-most limit of the waste was the filled in gulley indicated on Figure 3. The geological log of borehole OW4 (Appendix A) bears this out. The east, west and southernmost limits of landfilling are designated by the steep slopes on the north side of Otter Creek (Figure 3).

3.1.3 Characterization of Waste

The major waste components of the landfill, based on the results of the drilling program, include: asphalt, domestic refuse, plastic, metal, fabric, wire fencing, paper, bricks, and charred/burnt wood and branches. This concurred with the information provided by Township officials. A large proportion of silty sandy soil had been mixed in with the waste, and the landfilling area had been capped with approximately 0.4 to 0.7 metres of a similar material and had been revegetated. Township of Norwich officials indicated that the majority of the garbage

had been disposed of on the eastern side of the disposal area, and that the remainder of the site had been covered with relatively clean fill, including charred wood and branches, soil, rocks and boulders and blocks of concrete. This was confirmed by visual inspection of the western periphery of the site. The known/suspected extent of the waste and fill is depicted in Figure 8.

3.2 SITE HYDROGEOLOGY

3.2.1 Groundwater Flow Direction

Groundwater in the shallow overburden generally flows from the west to east across the waste disposal area (Figures 9 and 10), and appears to be controlled by the till elevation. The water table is relatively flat across of the site but is high where the till is elevated. Along the northern limit of the site, however, the flow pattern is irregular due to the presence of a relict gully which had been filled and covered.

During the 1988 mid-summer drought, the static water level was located immediately below the waste in OW7-S and OW7-D. In mid-August, however, the water level had risen to 0.5 metres above the base of the waste (Table 3, Figures 11 and 12). Given the apparent groundwater flow direction, it is expected that if any leachate plume exists it would most likely impact monitors OW2, OW7, OW1 and OW6, and that OW3 and OW5 would indicate background levels of constituent chemical parameters in the groundwater.

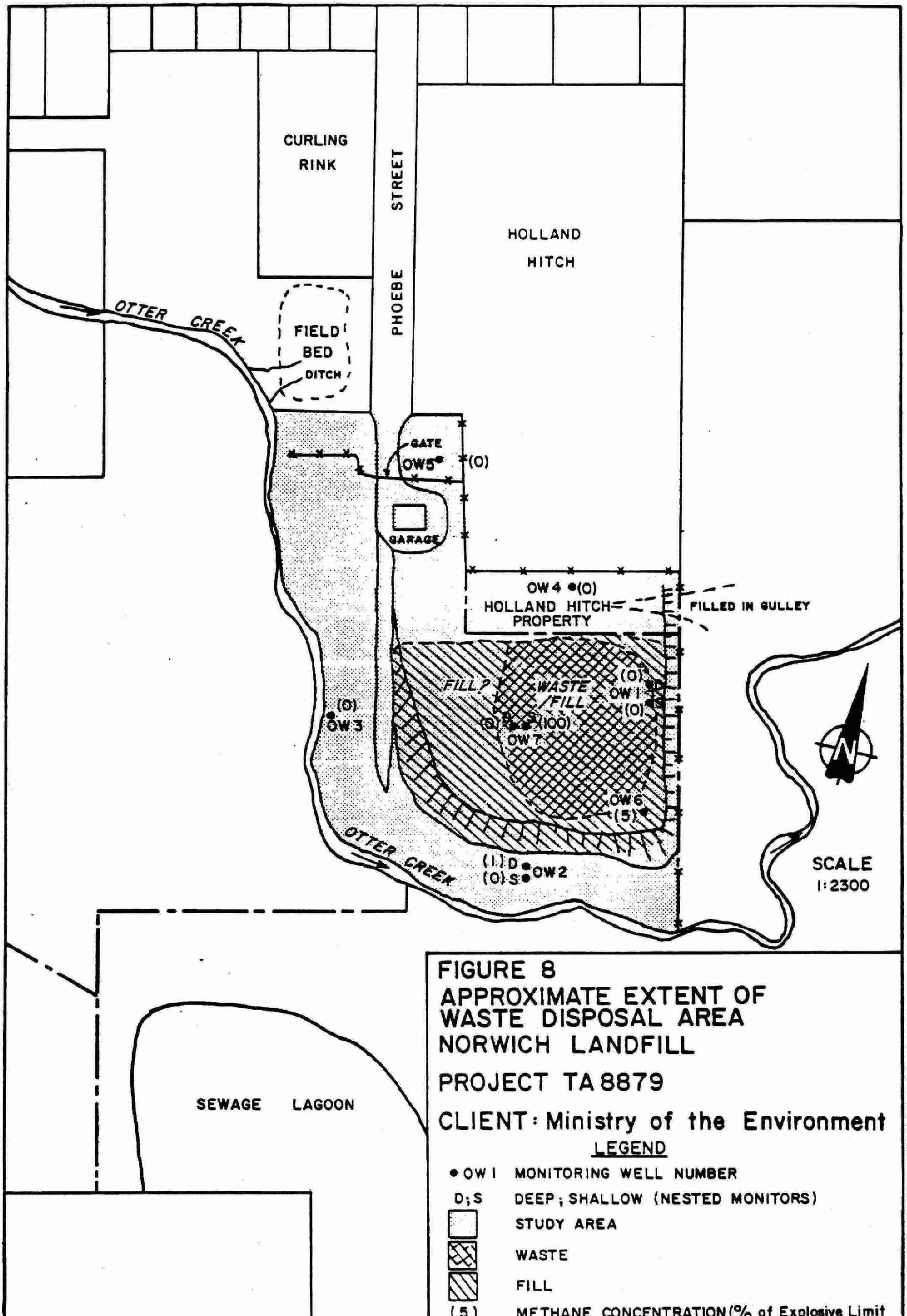


FIGURE 8
APPROXIMATE EXTENT OF
WASTE DISPOSAL AREA
NORWICH LANDFILL

PROJECT TA 8879

CLIENT: Ministry of the Environment

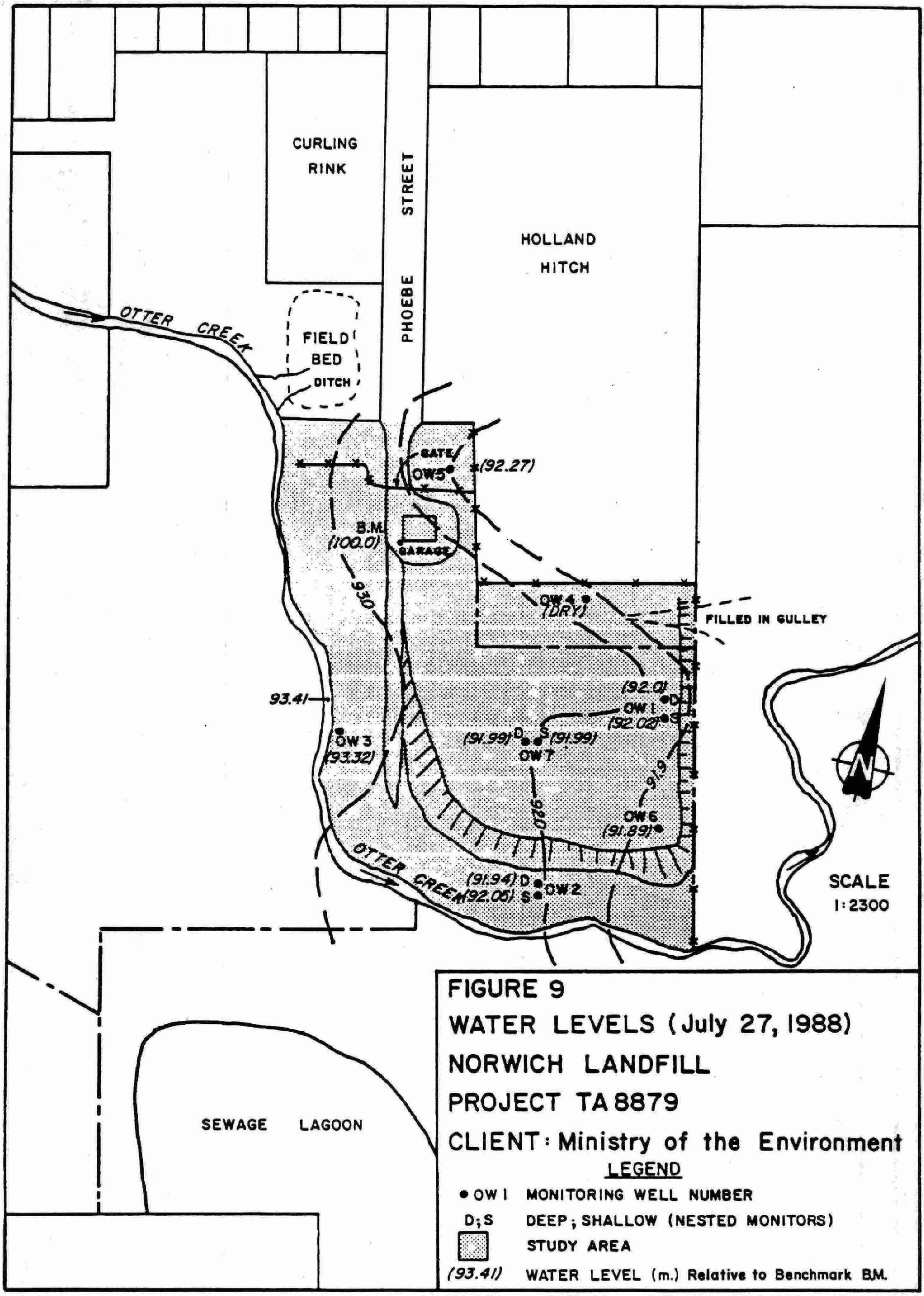


FIGURE 9

WATER LEVELS (July 27, 1988)

NORWICH LANDFILL

PROJECT TA 8879

CLIENT: Ministry of the Environment

LEGEND

• OW 1	MONITORING WELL NUMBER
D; S	DEEP; SHALLOW (NESTED MONITORS)
[shaded box]	STUDY AREA
(93.41)	WATER LEVEL (m.) Relative to Benchmark B.M.

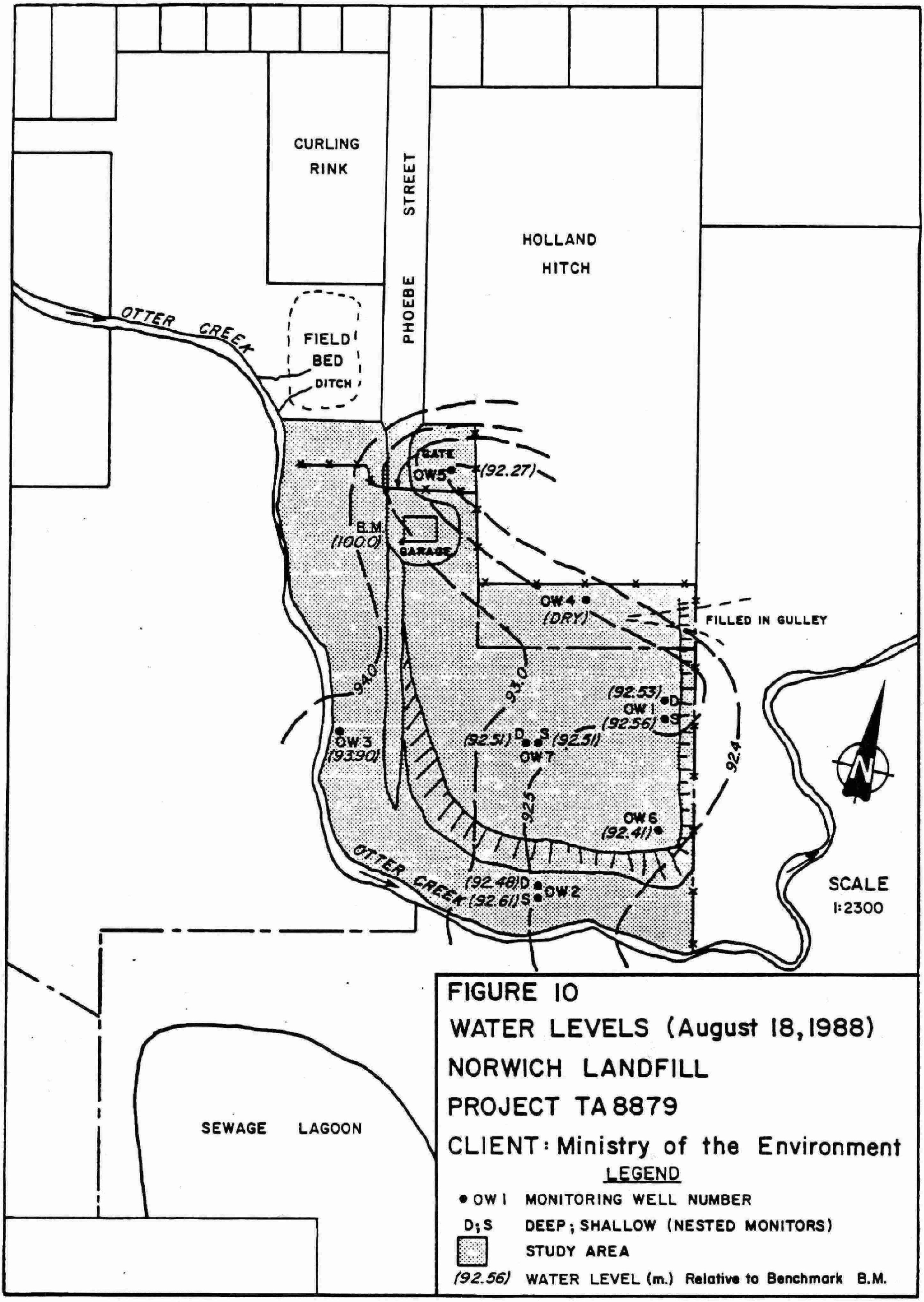


FIGURE 10
WATER LEVELS (August 18, 1988)
NORWICH LANDFILL
PROJECT TA 8879
CLIENT: Ministry of the Environment

LEGEND

- • OW 1 MONITORING WELL NUMBER
- D; S DEEP; SHALLOW (NESTED MONITORS)
- STUDY AREA
- *(92.56)* WATER LEVEL (m.) Relative to Benchmark B.M.

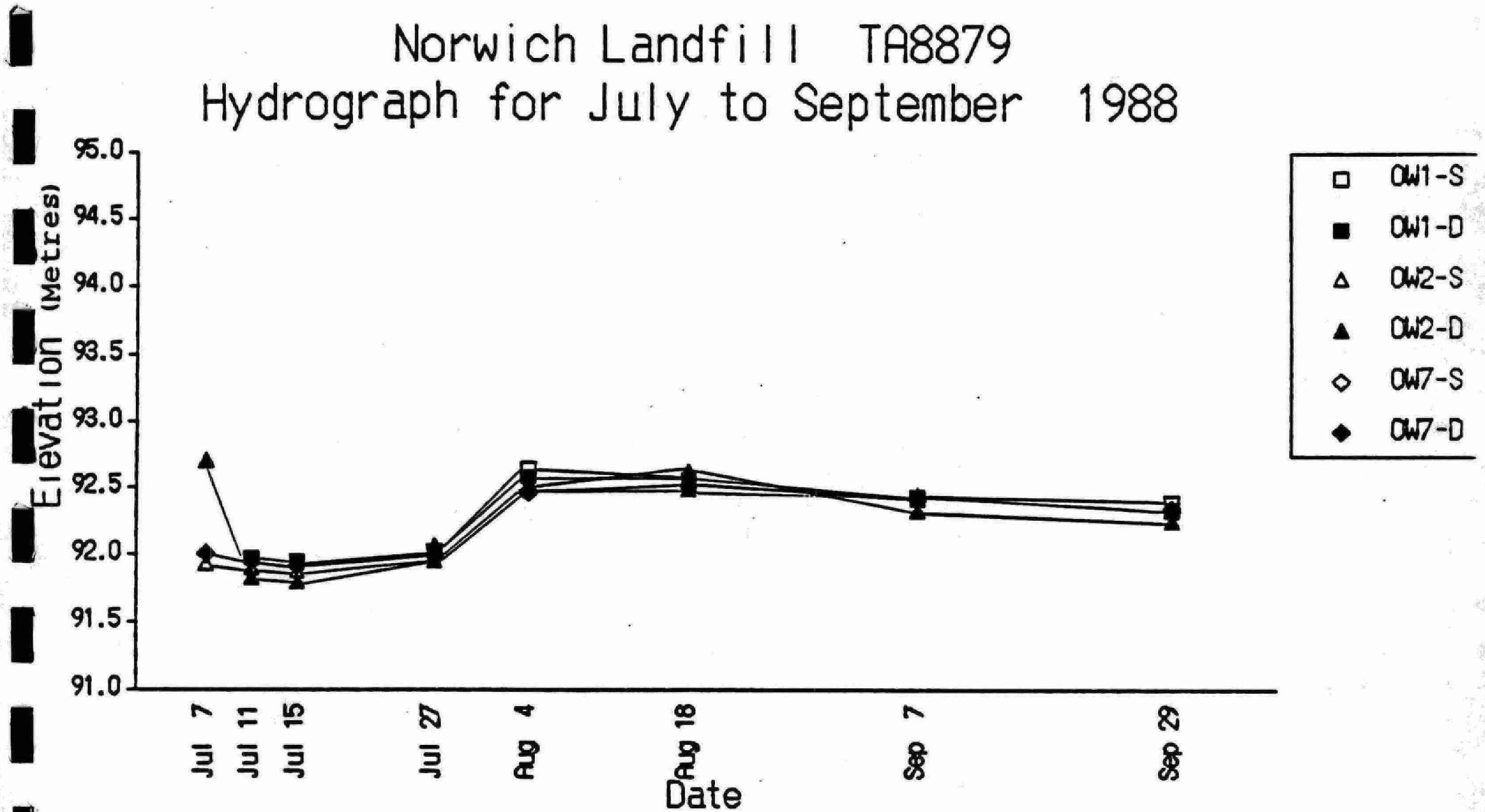
WELL NO.	ELEVATION OF GROUND SURFACE* [m]	ELEVATION OF TOP OF CASING* [m]	July 7/88	July 11/88	July 15/88	July 27/88	Aug 4/88	Aug 18/88	Sept 7/88	Sept 29/88
OW1-S	97.56	98.34	Dry	Dry	Dry	92.02	92.64	92.56	92.42	92.39
OW1-D	97.56	98.41	---	91.97	91.94	92.0	92.58	92.53	92.41	92.33
OW2-S	94.10	95.04	91.92	91.89	91.87	92.05	---	92.48	92.43	92.34
OW2-D	94.18	95.02	92.69	91.82	91.79	91.94	92.51	92.61	92.32	92.24
OW3	95.15	96.22	93.16	93.11	93.07	93.32	94.11	93.90	93.75	93.54
OW4	98.84	99.68	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry
OW5	99.56	99.97	91.75	91.73	91.72	91.9	92.12	92.27	92.34	92.32
OW6	96.65	97.14	91.86	91.83	91.80	91.89	---	92.41	92.28	92.2
OW7-S	97.77	98.32	---	91.95	91.92	91.99	92.47	92.51	92.41	92.34
OW7-D	97.76	98.70	92.00	91.95	91.92	91.99	92.46	92.51	92.41	92.33

* Relative to benchmark (ground surface at southwest corner of shed - 100 metres)

TABLE 3

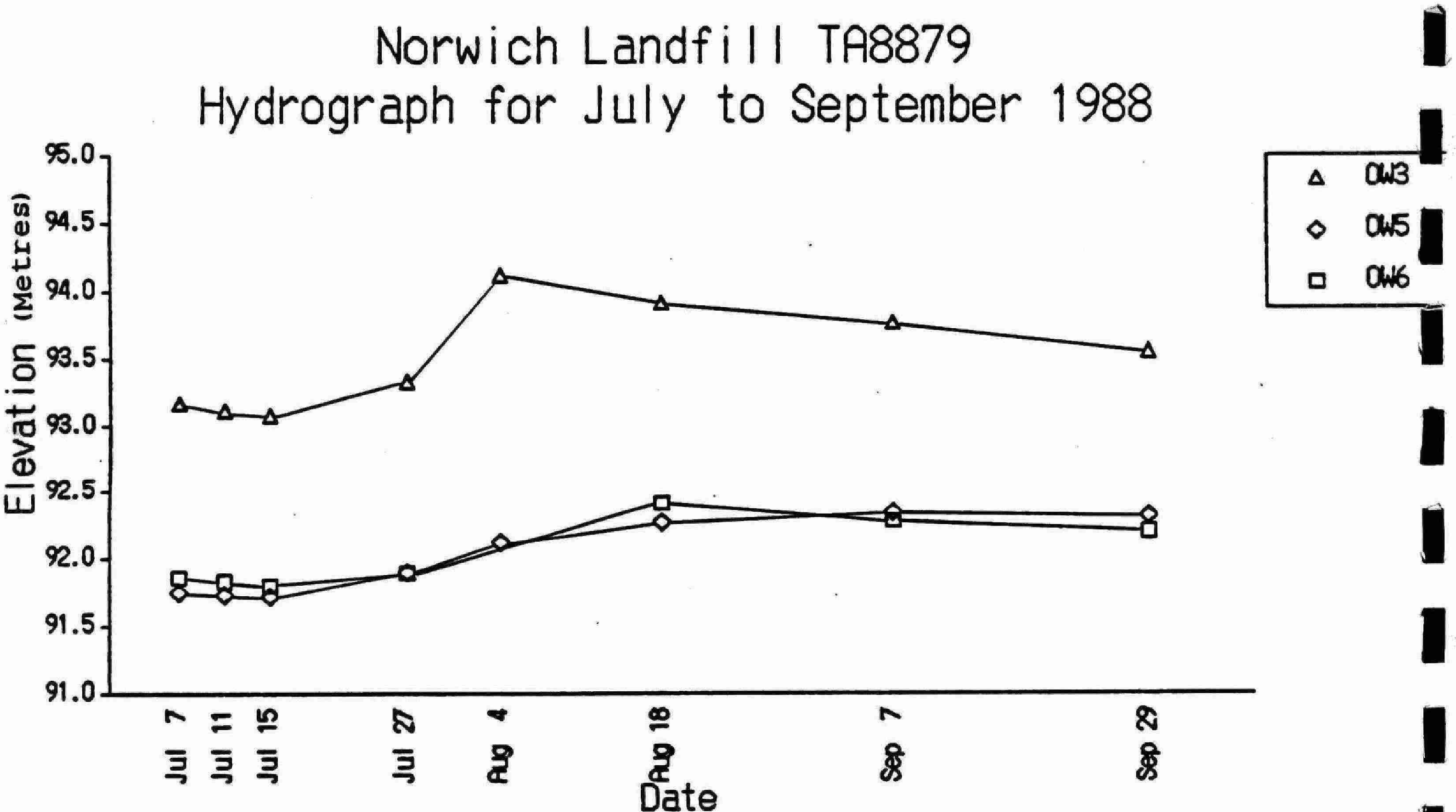
WATER LEVELS

FIGURE 11.



Norwich Landfill TA8879
Hydrograph for July to September 1988
Elevation (Metres)
95.0
94.5
94.0
93.5
93.0
92.5
92.0
91.5
91.0
Jul 7
Jul 11
Jul 15
Jul 27
Aug 4
Aug 18
Sep 7
Sep 29
Date
OW1-S
OW1-D
OW2-S
OW2-D
OW7-S
OW7-D

FIGURE 12.


Norwich Landfill TA8879
Hydrograph for July to September 1988
Elevation (Metres)
95.0
94.5
94.0
93.5
93.0
92.5
92.0
91.5
91.0
Jul 7
Jul 11
Jul 15
Jul 27
Aug 4
Aug 18
Sep 7
Sep 29
Date
OW3
OW5
OW6

The average depth of the water table below ground surface is approximately 7 metres at the north edge of the site, 5 metres in the middle of the waste disposal area, and about 2 metres along the lower edge of the slope face. The horizontal hydraulic gradient (from the west to east across the site, i.e. from OW3 to OW1) within the sand and gravel unit above the till is about 0.01 (Appendix B).

It appears, from water level data collected to date, that groundwater flow is mainly horizontal across the landfill, although a downward vertical gradient (on the order of 0.02) exists at OW1 during and after significant precipitation (i.e. during infiltration). A downward gradient of 0.11 exists at OW2 on a seemingly permanent basis, as would be expected since the well screens are situated above and within a relatively low permeability till.

3.2.2 Hydraulic Conductivity and Groundwater Flux

Response tests (i.e. bail tests) were performed at six of the ten monitoring wells, and repeat tests were conducted at OW1-D and OW2-D (Appendix B). The average hydraulic conductivity of the (silty) sand and gravel unit above the till (based on test results from OW1-D, OW2-S, OW5 and OW7-D) is on the order of 10^{-5} to 10^{-6} m/s, indicating a relatively permeable unit (Table 4). The hydraulic conductivities of the till unit (OW2-D) and the clay-silt alluvial deposit (OW3) are on the order of 10^{-8} m/s, indicating a lower permeability unit.

MONITORING WELL NO.	HYDRAULIC CONDUCTIVITY* [m/s]	GEOLOGIC MATERIAL
OW1-D	1.03×10^{-6} 1.05×10^{-6}	layered silty sand and gravel
OW2-S	1.13×10^{-6}	coarse sand and gravel, some silt
OW2-D	7.31×10^{-8} 7.74×10^{-8}	stony sandy silt till
OW3	8.56×10^{-8}	silty sand to clayey silt
OW5	8.75×10^{-6}	silty sand and gravel
OW7-D	1.38×10^{-6}	sand and gravel, some silt

* Determined from Slug Test Analysis (Appendix B)

TABLE 4

SUMMARY OF HYDRAULIC CONDUCTIVITY VALUES

Assuming west to east flow across the landfill, an upper limit hydraulic conductivity of 10^{-5} m/s, saturated thickness of sand and gravel unit of 2.5 metres, a horizontal hydraulic gradient of 0.01, and an eastern landfill boundary with a length of 125 metres, the off-site groundwater flux is:

$$Q = KiA$$
$$= 10^{-5} \times 0.01 \times 2.5 \times 125$$
$$= 3.1 \times 10^{-5}\ m^3/s$$
$$= 986\ m^3/year\ (1.9\ L/min)$$

where

Q = groundwater flux (m^3/s)
K = hydraulic conductivity (m/s)
i = hydraulic gradient (/)
and A = saturated thickness x length (m^2)

Based on a site area of 125 X 125 metres, the average annual infiltration of precipitation into the landfill would be on the order of 0.06 metres, indicating that the infiltration into the landfill is very low.

3.3 WATER QUALITY

Two surface water samples from Otter Creek and six groundwater samples from the landfill monitoring wells were collected and analysed with respect to general water quality. The general analytical results are presented in Table 5, and the concentrations of selected chemical parameters have been plotted in Figures C-1 to C-4 (Appendix C). Results of the volatile organic scan and the analysis for base neutral/acid extractables are also included in Appendix C.

The quality of both surface and groundwater in the vicinity of the landfill is generally good, with a few minor exceptions.

PARAMETER	SAMPLE LOCATION							
	CS1	CS2	OW1-D	OW2-S	OW3	OW5	OW7-S	OW7-D
Alkalinity	183	182	380	290	330/340	360	760	470
Hardness	258	252	393	394	317	388	1210	1009
TKN	1.66	1.54	0.57	0.33/0.32	2.0	0.34	1.01	0.51
Ammonia-N	0.10	0.10	0.07	0.14	2.0/2.0	0.09	0.32	0.12/0.11
Nitrate-N	5.2	5.3	0.2	<0.2	<0.2/<0.2	1.7	<0.5	<0.5
Nitrite-N	0.08	0.12	<0.2	<0.2	<0.2/<0.2	<0.2	<0.5	<0.5
Organic-N	1.66	1.44	0.50	0.19	---	0.25	0.69	0.40
Zinc	<0.01	<0.01	0.01/0.02	0.01	0.01/0.01	0.01	0.02	0.02
DOC	8.0	8.0	4.0	2.5	3.5	2.0	10.5	6.0
Iron	<0.02	<0.02	<0.02	0.16	<0.02	<0.02	0.06	3.8
Manganese	0.02/0.01	0.02	0.59	0.39	0.23/0.24	0.30	1.95	1.52
Phenols	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Sodium	12.0	11.5	34	42	31	28	182	45
Chloride	28	30	41	90	16.2/16.1	26	240	63
Sulphate	43	43	67	72	37/39	51	450	460
Copper	<0.005	<0.005	0.005	<0.005	<0.005	<0.005	0.005	0.005
Barium	0.06	0.06	0.07	0.20	0.34	0.08	0.08	0.06
Cadium	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Chromium	<0.01	<0.01	0.01/0.01	0.01	0.01/0.01	0.01	0.02	0.02
Lead	<0.05	<0.05	<0.05	<0.05	<0.5	<0.05	<0.05	<0.05
Fluoride	0.24	0.20	0.60	0.50	0.40/0.40	0.40	0.75	<0.25
Calcium	79	77	103	115/114	89	106	330	320
Magnesium	14.8	14.5	33	26	23	30	94	51
Cobalt	<0.01	<0.01	0.01	0.01	<0.01	0.01	0.02	0.03
Nickel	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	0.02
Beryllium	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Molybdenum	0.02	0.02	<0.02	<0.02	0.04	<0.02	<0.02	<0.02
Vanadium	0.005	<0.005	0.005	0.005	0.005	<0.005	0.015	0.015
Aluminum	0.10	0.08	0.10	0.14	0.12	0.10	0.28	0.32
Potassium	5.6	5.5	28	5.3	6.1	18.1	3.2	1.85
Strontium	0.58	0.57	0.54	0.61	2.3	0.96	0.90	0.76
Bromide	<0.2	<0.2	<0.5	<0.5	<0.5/<0.5	<0.5	<1.0	<1.0
BOD_5	5	5						

Note: All units are mg/L

TABLE 5

RESULTS OF CHEMICAL ANALYSIS

Concentrations of organic nitrogen (ranging from 0.19 to 1.66 mg/L) which exceed the maximum desirable concentration (MDC) of 0.15 mg/L, as outlined in the MOE Drinking Water Objectives, were found in all samples analysed (Figure C-1). It should be noted that the MOE Drinking Water Objectives are used as a means of comparison only: this water is not used for drinking purposes. The highest concentrations of organic nitrogen (1.66 and 1.44 mg/L) were detected in creek samples CS1 (downgradient) and CS2 (upgradient) respectively. Excess organic nitrogen may be associated with organic fouling; taste and odour problems have usually been associated with organic nitrogen levels of 0.15 to 0.2 mg/L or greater (MOE, 1983).

The samples from Otter Creek also contained levels of nitrate (as nitrogen) which were significantly greater than those present in the landfill: the concentrations of nitrate in CS1 and CS2 were 5.2 and 5.3 mg/L, compared with 0.2 mg/L in OW1-D. Groundwater from OW5, which is upgradient of the landfill, but downgradient of the curling rink field bed, contained 1.7 mg/L nitrate.

Concentrations of dissolved organic carbon (DOC) exceeded the MDC of 5.0 mg/L total organic carbon in CS1 (8.0 mg/L), CS2 (8.0 mg/L), OW7-S (10.5 mg/L) and OW7-D (6.0 mg/L). Water from the remaining monitors, three of which are situated between OW7 and Otter Creek, ranged from 2.0 to 4.0 mg/L (Figure C-2). High levels of organic carbon in water may result either from naturally occurring matter, such as would be found in a creek bed (CS1 and CS2), or from man-derived sources (i.e. waste); elevated

organic carbon is frequently associated with colour, taste, odour and turbidity difficulties.

As indicated in Figures C-1, C-3 and C-4, the groundwater directly beneath the waste (i.e. from OW7-S and OW7-D) is characteristically elevated in alkalinity, hardness, ammonia nitrogen, DOC, manganese, sodium, chloride, sulphate, calcium and magnesium. Groundwater from monitor number OW7-S, followed closely by OW7-D, shows the most impact from the landfill, as would be expected since the wells are screened directly below the waste in relatively permeable sand and gravel. Alkalinity, hardness, organic nitrogen, DOC, manganese and sodium are near or in excess of the desired concentrations at OW1-S and OW7-D, while only manganese and sodium are in excess of desirable limits at each of the remainings landfill monitors. It should be noted that these concentrations are relatively low in comparison with typical landfills (Freeze & Cherry, 1979, pg 435).

3.4 LANDFILL-RELATED GAS HAZARDS

The concentration of landfill-related gas was monitored using a combustable gas indicator at an ambient air temperature of approximately 15 degrees Celsius. Potential gas hazards were not detectable above the ground surface on or around the waste disposal area. Measurable concentrations of potentially explosive gases (Figure 8) were detected at three of the ten monitoring well locations (OW2-D, OW6, and OW7-S). The concentrations of explosive gases at OW2-D and OW6 were 1%

(0.047% methane) and 5% (0.235% methane) of the explosive limit (respectively). The indicator moved off-scale at OW7-D, signifying concentrations of methane in excess of the lower explosive limit.

4.0 CONCLUSIONS

Based on the results of this study and the preliminary assessment, the following conclusions can be drawn:

1) The quantity of data and information collected prior to and during the course of this investigation is sufficient to allow the specific study objectives to be addressed.

2) The area used for waste disposal at the Norwich Landfill is limited to those lands to the south of a buried gully on the northeast corner of the property, and those north of the steep slope on the north side of Otter Creek.

3) The type of waste disposed of on-site appears to be limited to domestic refuse, fill, and covering material. Industrial waste does not appear to have been deposited on-site.

4) The landfill is underlain by approximately two to four metres of sand and gravel and at least six metres of dense stony sandy silt till.

5) Groundwater flow in the shallow zone is generally from west to east across the site, with minor components to the south and southeast. Small vertical hydraulic gradients exist at some locations on-site.

6) The groundwater flux from the site (in a horizontal direction) is on the order of 1000 m^3/year (1.9 Lpm). The maximum estimated infiltration of precipitation

into the waste, based on this flux, is approximately 0.06 metre/year.

7) Typically, groundwater which has been impacted by the landfill (i.e. directly beneath the waste) has elevated concentrations of alkalinity, hardness, ammonia nitrogen, DOC, manganese, sodium, chloride, sulphate, calcium and magnesium. Monitoring wells at the downgradient boundaries of the site indicate that groundwater migrating off-site contains levels of manganese and sodium which slightly exceed the MOE drinking water criteria, which are used as a means of comparison. Water sampled from the creek, however, has acceptable levels of these two parameters. Water from these sources is not used for domestic consumption.

8) Based on the water quality of analysis of creek samples CS1 and CS2, Otter Creek does not appear to have been impacted by the presence of the landfill. It does contain elevated levels of nitrate, organic nitrogen and total kjeldahl nitrogen which are in excess of those concentrations occurring in groundwater directly beneath the waste. It can be concluded from this that contamination from another source, such as the sewage lagoon to the south of Otter Creek, is the probable cause of these concentrations. A background monitor (OW5) also appears to have been slightly impacted by nitrate contamination, possibly from an upgradient field bed located near the curling rink.

9) Domestic and municipal wells in the vicinity are not likely to be adversely affected by any off-site leachate migration from the waste disposal area, given the known groundwater flow direction (i.e. away from the local wells), quality of water on-site, and estimated groundwater flux.

10) A potential landfill gas problem exists in the centre of the landfill (OW7-S) where gas concentrations were found to be in excess of 10% of the lower explosive limit (>.047% methane). Minor concentrations were detected in two other landfill monitoring wells, but there does not appear to be any lateral methane migration. No methane was detectable above ground surface. There are no structures in the immediate area of the landfill which could potentially collect gas, and in the present state of the landfill, there is no methane hazard.

5.0 RECOMMENDATIONS

The following action is recommended, based on the findings of this investigation.

1) There is no immediate gas hazard if the landfill remains in its present state. However, if any future excavation or development of the site were to take place, this situation could change. Open flames or sparks should not be used in the vicinity of OW-7.

6.0 REFERENCES

Barnett, P.J. and Girard, C.K.
1982 *Quaternary Geology of the Tillsonburg Area;* Ontario Geological Survey, Map 2473, Quaternary Geology Series, Scale 1:50000, Geology 1976.

Freeze, A.R. and Cherry, J.A.
1979 *Groundwater;* Prentice-Hall, Inc., Englewood Cliffs, N.J. 07632.

Ministry of the Environment
1979 *Water Well Records For Ontario - Huron, Oxford, Perth 1946-1976;* Water Resources Branch, Water Resources Bulletin 2-24, Groundwater Series.

Ministry of the Environment
1983 *Ontario Drinking Water Objectives*

Sibul, U.
1969 *Water Resources of the Big Otter Creek Drainage Basin;* Ontario Water Resources Commission, Division of Water Resources, Water Resources Report 1.

APPENDIX A

Well No.	Elevation of Ground Surface* [m]	Elevation of Top Casing* [m]	Screened Interval [m]below Ground Surface	Sandpack [m]below Ground Surface	Seal [m]below Ground Surface
OW1-S	97.56	98.34	4.13-5.65	3.5-5.7	2.9-3.5
OW1-D	97.56	98.41	8.01-8.77	7.5-8.8	3.7-4.6 5.2-7.5
OW2-S	94.10	95.04	2.53-4.05	1.8-4.3	1.2-1.8
OW2-D	94.18	95.02	8.31-9.83	8.3-9.8	7.0-8.3
OW3	95.15	96.22	2.01-3.53	1.7-3.7	1.1-1.4
OW4	98.84	99.68	1.8 -3.32	1.5-3.3	1.2-1.5
OW5	99.56	99.97	8.71-10.23	7.7-10.2	4.0-5.8 6.7-7.7
OW6	96.65	97.14	3.76-5.28	3.2-5.3	2.6-3.2
OW7-S	97.77	98.32	4.22-6.50	3.9-6.5	3.3-3.9
OW7-D	97.76	98.70	7.80-8.56	7.5-8.6	5.5-7.5

* Relative to Local Benchmark - Ground Surface at southwest corner of shed - taken to be 100 metres.

TABLE A-1

DETAILS OF MONITORING WELL INSTALLATION

BOREHOLE NO. OW1

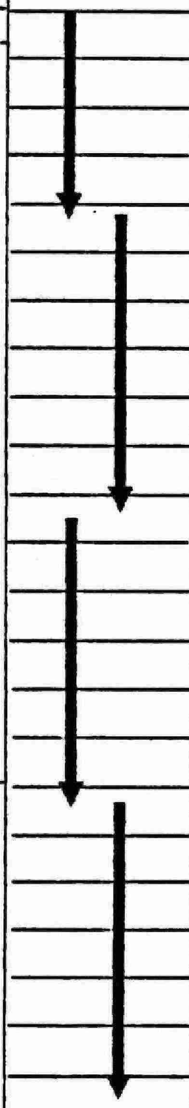
PROJECT Norwich Landfill TA3379 GEOLOGIST BJB

CLIENT MOE DATE July 6, 7, 1988

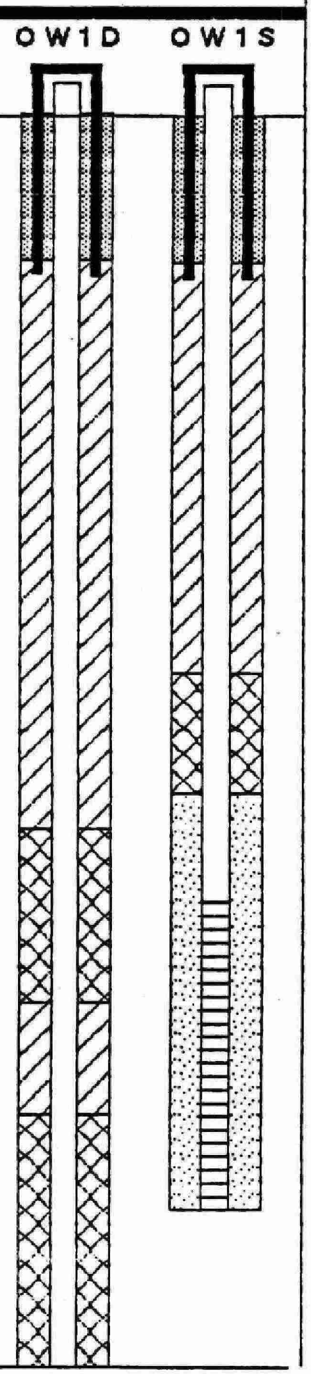
BOREHOLE TYPE Hollow Stem Auger SAMPLE TYPE Continuous

DEPTH metres	DESCRIPTION
0	COVER - sandy
	FILL - sandy - asphalt
1	- black/brown - sand, silt and stones - some brick fragments
2	- changes to orange/brown
3	- orange, black and white - clay, silt, sand, pebbles mixed with charred material and glass - rusty stain, iron odour - red/brown colour
4	medium to coarse SAND and GRAVEL, interlayered with silt and silty clay, moist. - silt with stones, iron and black stain
5	- sand and gravel, slight stain - brown silt, silty clay - sand and gravel, no stain
6	

SAMPLE INTERVAL



GROUND WATER MONITORS

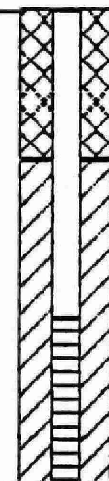


BOREHOLE NO. OW1 . CONTINUED

PROJECT Norwich Landfill TA8879 GEOLOGIST BJB

CLIENT MOE DATE July 6, 7, 1988

BOREHOLE TYPE Hollow Stem Auger SAMPLE TYPE Continuous

DEPTH metres	DESCRIPTION	SAMPLE INTERVAL	GROUND WATER MONITORS
6.5			OW1D CONTINUED
7	(continued)		
8	- medium to coarse sand, pebbles - silty medium to fine sand, pebbles		
9	TILL - grey brown silty fine sand with pebbles, stiff, wet, dense		BOREHOLE TERMINATED

BOREHOLE NO. OW2

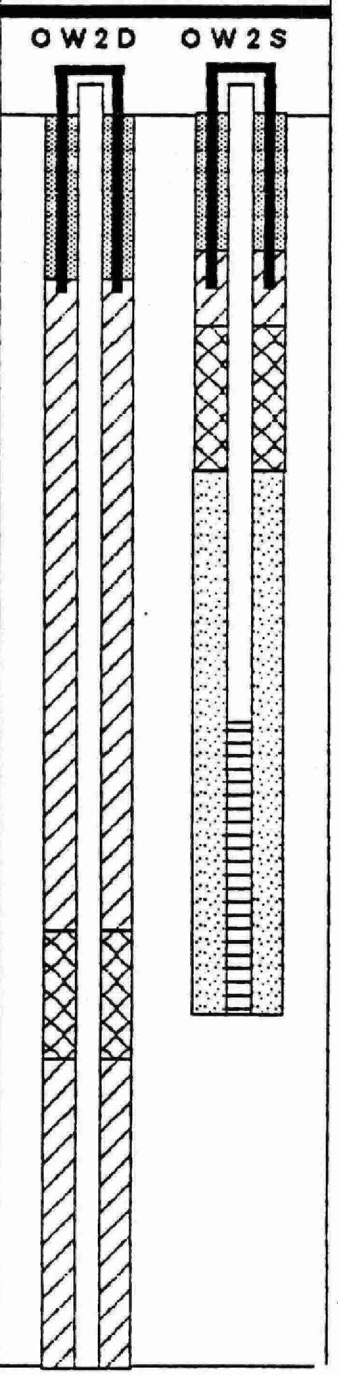
PROJECT Norwich Landfill TA8879 GEOLOGIST BJB

CLIENT MOE DATE July 5, 1988

BOREHOLE TYPE Hollow Stem Auger SAMPLE TYPE Split Spoon, Auger Sample

DEPTH metres	DESCRIPTION	SAMPLES TYPE	SAMPLES Bl. .5Ft.
0	TOPSOIL		
	- silty, sandy, brown	AS	
	- rootlets present		
1	Layered silty fine SAND		
	- brown medium sand layer.	SS	8/7 9/7
	- grey brown fine sandy clayey silt, some coarse sand, pebbles Moist.	SS	1/2 2/3
2	- grey brown silty very fine sand with coarse grains and pebbles. Close to saturation.	SS	7/7 9/13
3	- coarse sand and gravel, trace silt, saturated.	SS	8/25 26/33
4	TILL		
	- grey, very stony ,sandy silt, stiff and damp.	SS	16/46 55
	- as above.	SS	6/37 49
5		SS	-
6			

GROUND WATER MONITORS



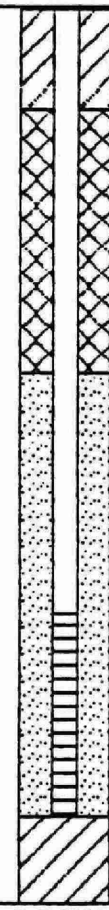
BOREHOLE NO. OW2 CONTINUED

PROJECT Norwich Landfill TA8879 GEOLOGIST BJB

CLIENT MOE DATE July 5, 1988

BOREHOLE TYPE Hollow Stem Auger SAMPLE TYPE Split Spoon, Auger Sample

DEPTH metres	DESCRIPTION	SAMPLES TYPE	SAMPLES Bl. .5 Ft.	GROUND WATER MONITORS
6.5				OW2D CONTINUED
7				
8	- grey brown silty sand with pebbles, saturated. - medium to fine samd layer	S S	8/20 24/26	
9	- layer of coarse sand	S S	20/40 36	
10	TILL - grey brown silty medium/fine sand with pebbles, saturated.			
11	- grey stony sandy silt - saturated	S S	16/33 36/42	
12				BOREHOLE TERMINATED



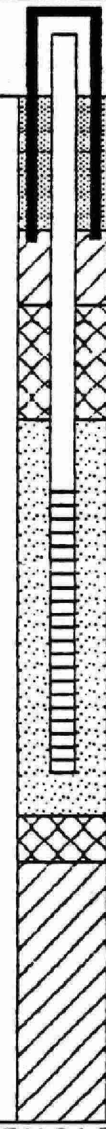
BOREHOLE NO. OW3

PROJECT Norwich Landfill TA8879 GEOLOGIST BJB

CLIENT MOE DATE July 5, 1988

BOREHOLE TYPE Hollow Stem Auger SAMPLE TYPE Split Spoon, Auger Sample

DEPTH metres	DESCRIPTION	SAMPLES TYPE	SAMPLES Bl. .5 Ft.	GROUND WATER MONITORS
0				
	TOPSOIL – silty fine sand	AS		
1	– brown silty clay, stiff, damp.	SS	2/2 3/4	
		SS	4/5 5/7	
2	– clayey silt, trace sand, some stones; brown, moist	AS		
	– grey brown silt and very fine sand, soft, loose.	SS	3/3 2/2	
3	– as above, a few pebbles	AS		
		SS	2/2 24/22	
	TILL, grey stony sandy silt till, very stiff.			
4	– as above, slightly damp.	SS	35/60	
5	– no sample.	SS	28/60	BOREHOLE TERMINATED
6				

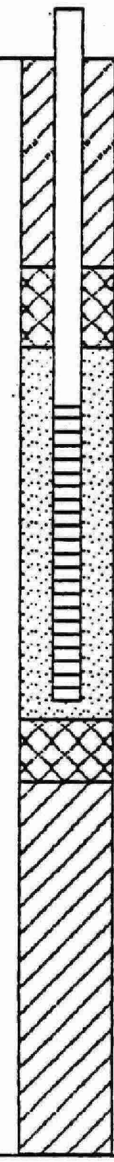


BOREHOLE NO. OW4

PROJECT Norwich Landfill TA8879 GEOLOGIST BJB

CLIENT MOE DATE July 6, 1988

BOREHOLE TYPE Hollow Stem Auger SAMPLE TYPE Continuous, Auger Sample

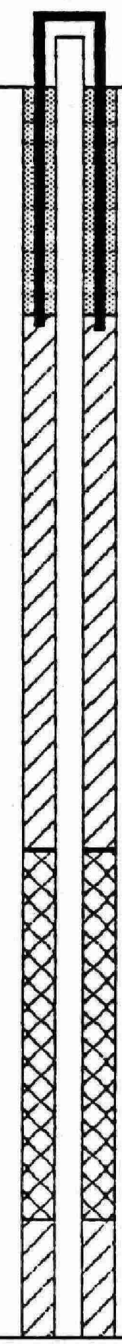
DEPTH metres	DESCRIPTION	SAMPLE INTERVAL	GROUND WATER MONITORS
0	TOPSOIL – dark brown, silty	AS	
	LAYERED FINE TO VERY FINE SAND, silty – orange brown at 60 cm.		
1	– layered fine to very fine clean sand, light brown		
	– as above		
2	– as above, some silt with white clay mottles.		
	– very fine sand and silt, brown, damp.		
	– very fine sand and silt interlayered with brown clayey silt.		
3			
	– clay silt layer		
4	– silty, fine to very fine sand		
	– very fine sand		
	– brown silt with clayey layers		
5	– fine to very fine sand with silt to silty clay layers		
	– layered clean fine sand		
6			BOREHOLE TERMINATED

BOREHOLE NO. OW5

PROJECT Norwich Landfill TA8379 GEOLOGIST BJB

CLIENT MOE DATE July 6, 1988

BOREHOLE TYPE Hollow Stem Auger SAMPLE TYPE Continuous

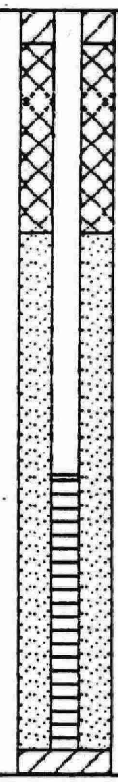
DEPTH metres	DESCRIPTION	SAMPLE INTERVAL	GROUND WATER MONITORS
0			
	TOPSOIL, brown silty fine sand		
	LAYERED BROWN FINE SAND, some silt.		
1	- orange brown silty laminae.		
	- layered silty fine to very fine sand.		
2	- 10 cm. brown clay layer at		
	- fine to very fine sand and silt.		
3	- layered brown silt some clay, sandy lenses.		
4	- as above - near saturation - alternating layers, brown silt and clay		
5	- layered fine to very fine sand, trace silt, damp		
	- layered fine to very fine sand		
6	SAND and GRAVEL, large stones (5 to 10 cm. diameter)		

BOREHOLE NO. OW5 CONTINUED

PROJECT Norwich L andfill TA8879 GEOLOGIST BJB

CLIENT MOE DATE July 6, 1988

BOREHOLE TYPE Hollow Stem Auger SAMPLE TYPE Continuous

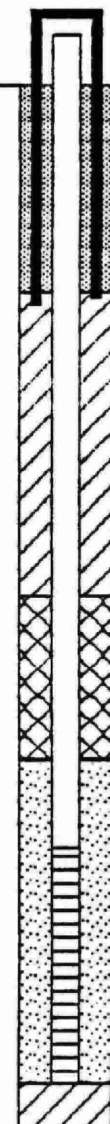
DEPTH metres	DESCRIPTION	SAMPLE INTERVAL	GROUND WATER MONITORS
6.5			CONTINUED
	– poorly sorted sand and gravel, cobbles.		
7			
	– layered medium to coarse sand and gravel with up to 8 cm. cobbles, very damp.		
8	– some silt present		
	– brown med to coarse sand, gravel, cobbles, saturated		
9	– silty and clayey lenses – as above		
	– as above		
10	– medium to coarse sand, pebbles		
	TILL – grey stony sandy silt till, stiff, dense		BOREHOLE TERMINATED
11			
12			

BOREHOLE NO. OW6

PROJECT Norwich Landfill TA8879 GEOLOGIST BJB

CLIENT MOE DATE July 6, 1988

BOREHOLE TYPE Hollow Stem Auger SAMPLE TYPE Continuous

DEPTH metres	DESCRIPTION	SAMPLE INTERVAL	GROUND WATER MONITORS
0			
	FILL - asphalt, burnt wood, black fill interlayered with rust coloured silty sandy, gravelly, fill.		
1			
2	- brown/black fill, charred wood chips - compact, dense brown/ black silt		
3			
	LAYERED SAND and GRAVEL		
4	- rust coloured coarse sand and gravel		
	- medium to coarse sand, black grading to orange. - medium sand, rusty bands		
5	- rusty coarse sand, gravel - very fine to medium sand interlayered with clayey silt		
	- medium sand with silt silt, gravel, large stones.		BOREHOLE TERMINATED
6			

BOREHOLE NO. OW7

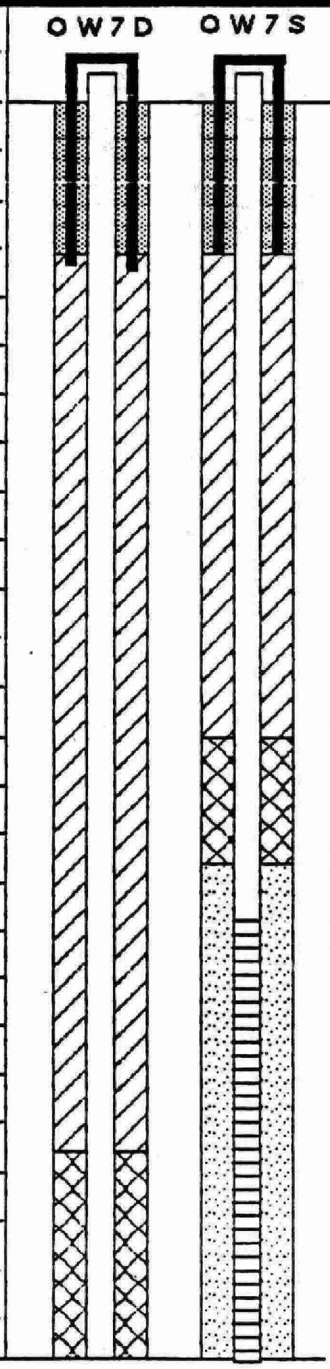
PROJECT Norwich Landfill TA8879 GEOLOGIST BJB

CLIENT MOE DATE July 7, 1988

BOREHOLE TYPE Hollow Stem Auger SAMPLE TYPE Continuous, Auger Sample

DEPTH metres	DESCRIPTION	SAMPLE INTERVAL
0	COVER – stony silty fine sand brown to darker brown with depth	AS
1	– brown silty clay	
	WASTE – asphalt, metal, paper, plastic, wire fencing, and domestic refuse interlayered with silty fine sand.	
2		
	– as above	
3		
	– as above	AS
4		
	– as above	
5		
	– near saturation	
6	LAYERED SAND, brown medium to fine, rusty stains, 1 to 3 cm. coarse sand layers	

GROUND WATER MONITORS

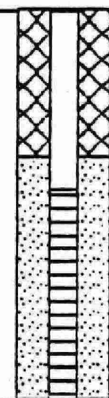


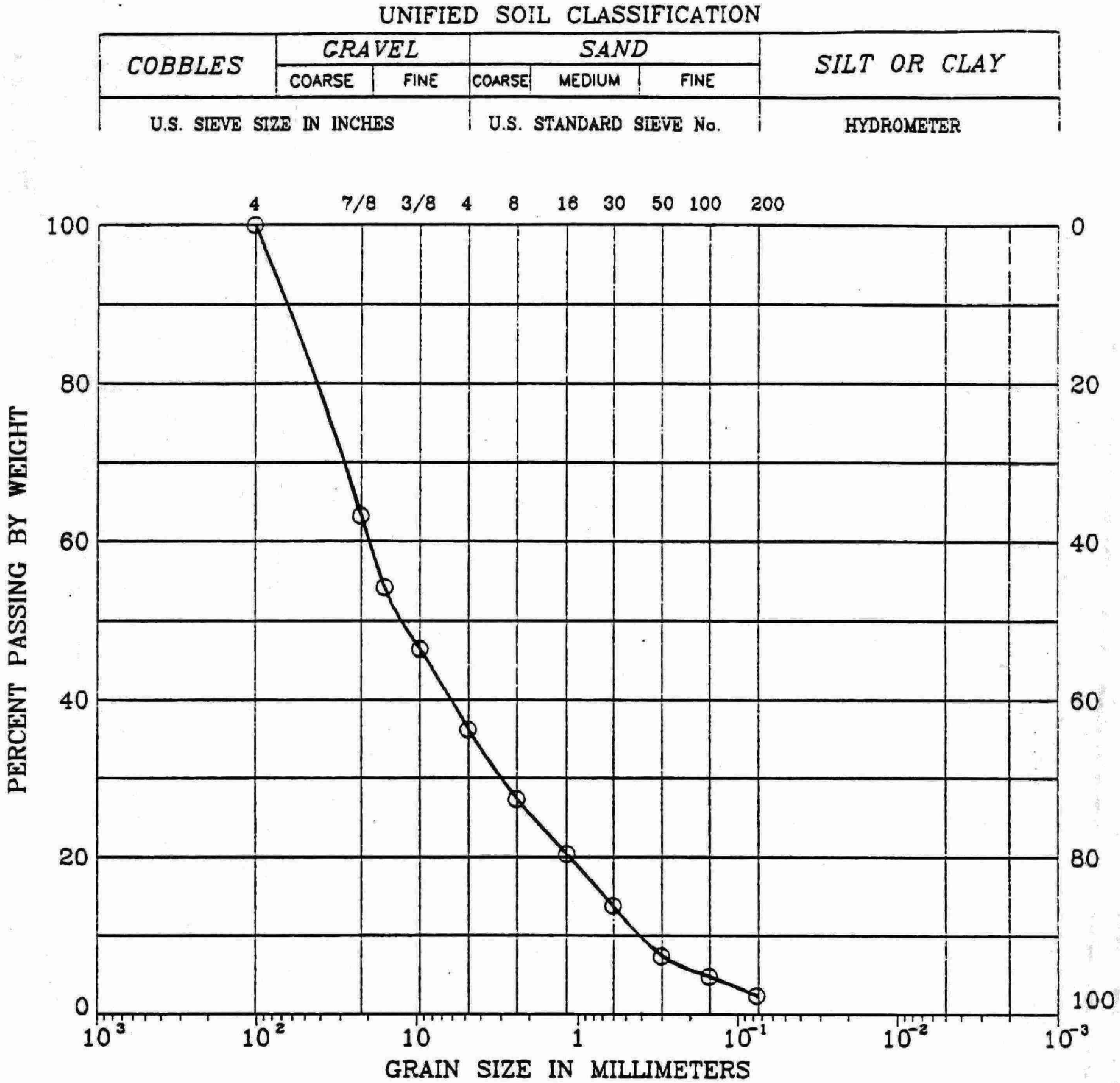
BOREHOLE NO. OW7 CONTINUED

PROJECT Norwich Landfill TA8879 GEOLOGIST BJB

CLIENT MOE DATE July 7, 1988

BOREHOLE TYPE Hollow Stem Auger SAMPLE TYPE Continuous, Auger sample

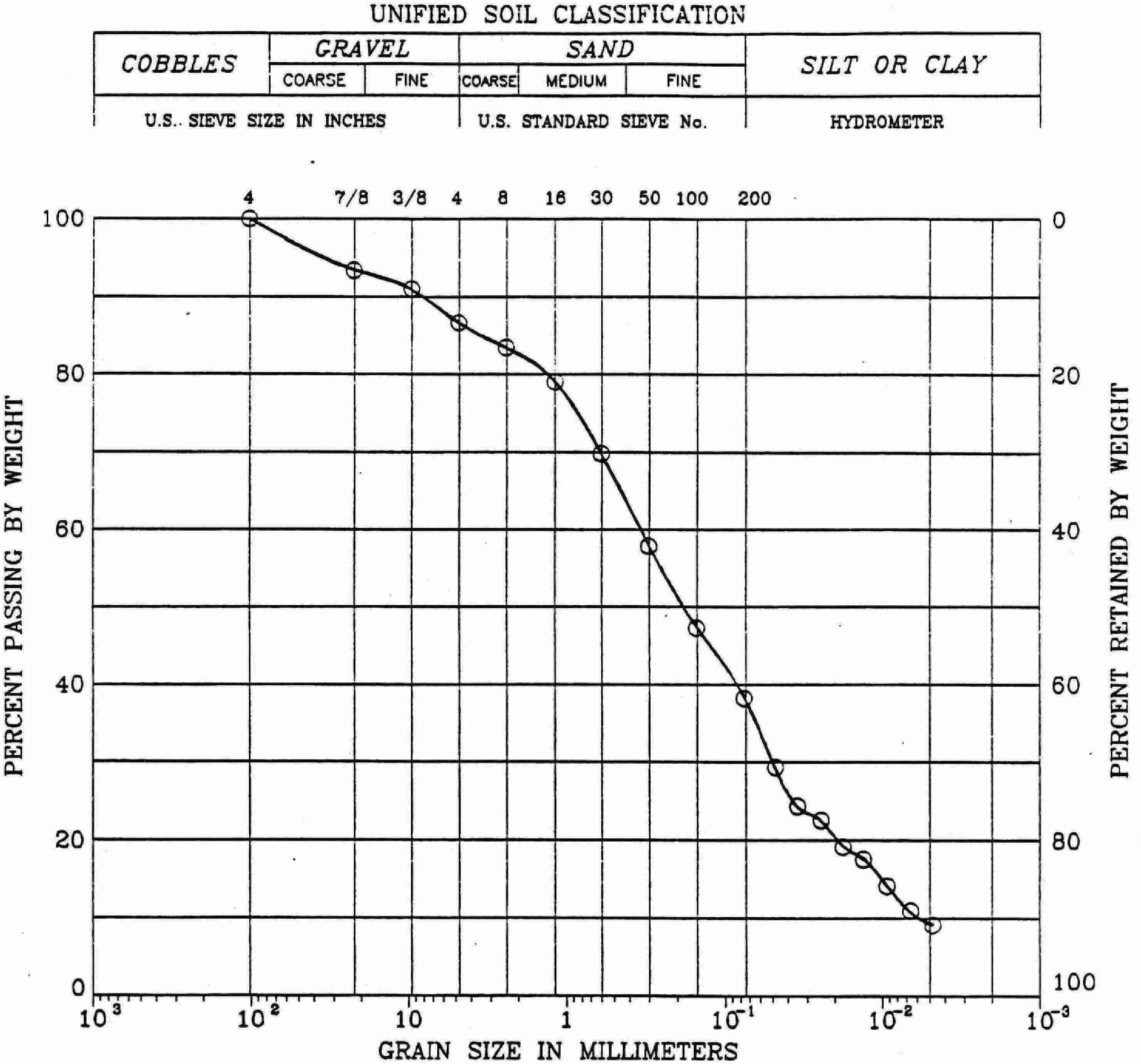
DEPTH metres	DESCRIPTION	SAMPLE INTERVAL	GROUND WATER MONITORS
6.5			CONTINUED
	- brown, silty, medium sand		
7	- clean medium sand		
	- coarse sand, stones and boulders.		
	- coarse sand and stones, gravel, silty lenses, boulders		
8	- brown clean medium sand		
	TILL - grey brown silty to clayey medium sand with gravel and rock fragments.		BOREHOLE TERMINATED
9			



SYMBOL	BORING	DEPTH (m)	LL (%)	PI (%)	DESCRIPTION
O	OW7	7.3–7.8			SAND AND GRAVEL

Remark :

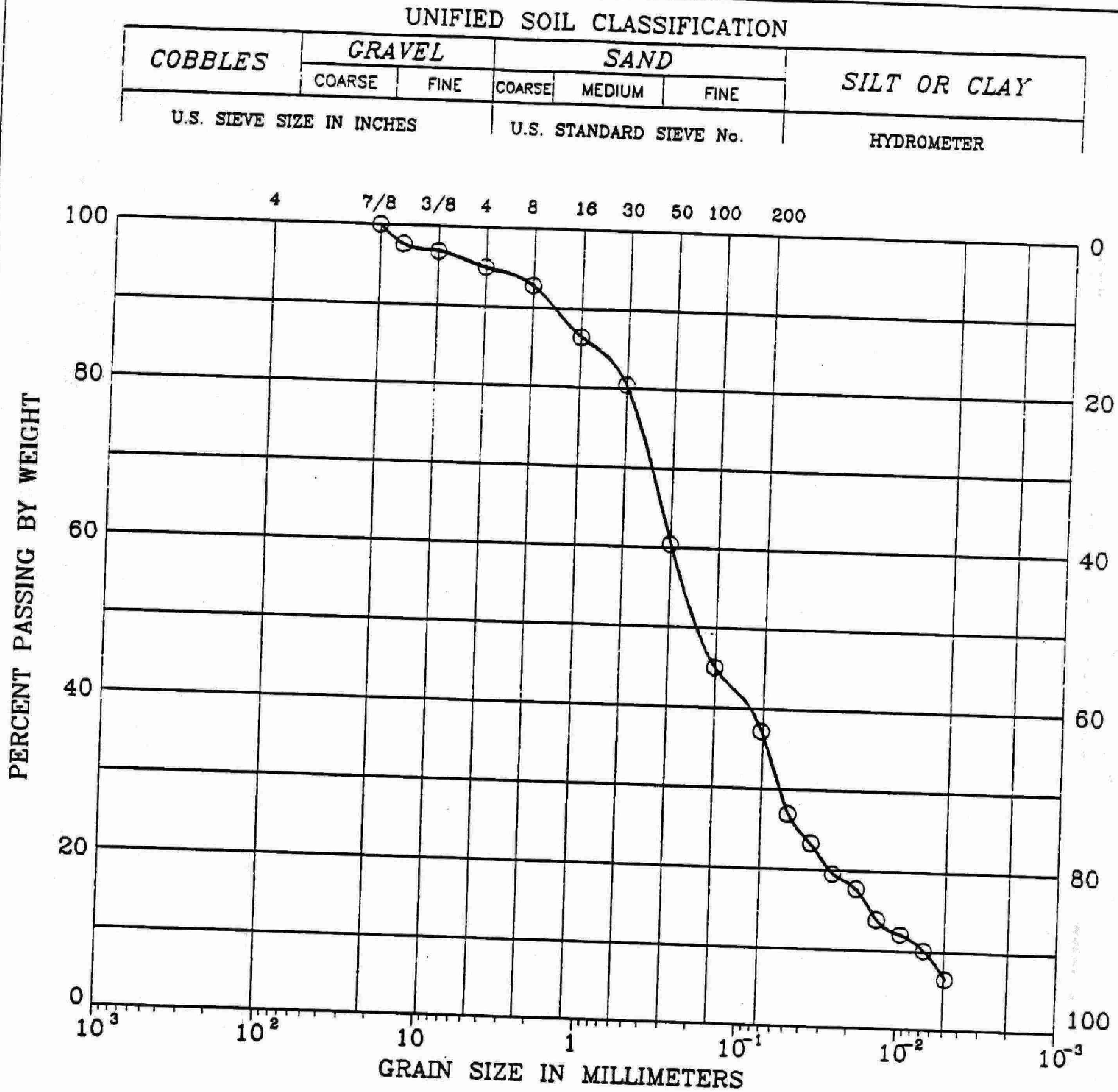
Project No. TA8879	TERRAQUA INVESTIGATIONS
ENE	GRAIN SIZE DISTRIBUTION Figure No. 1



SYMBOL	BORING	DEPTH (m)	LL (%)	PI (%)	DESCRIPTION
O	OW2	4.7			SILTY SAND

Remark :

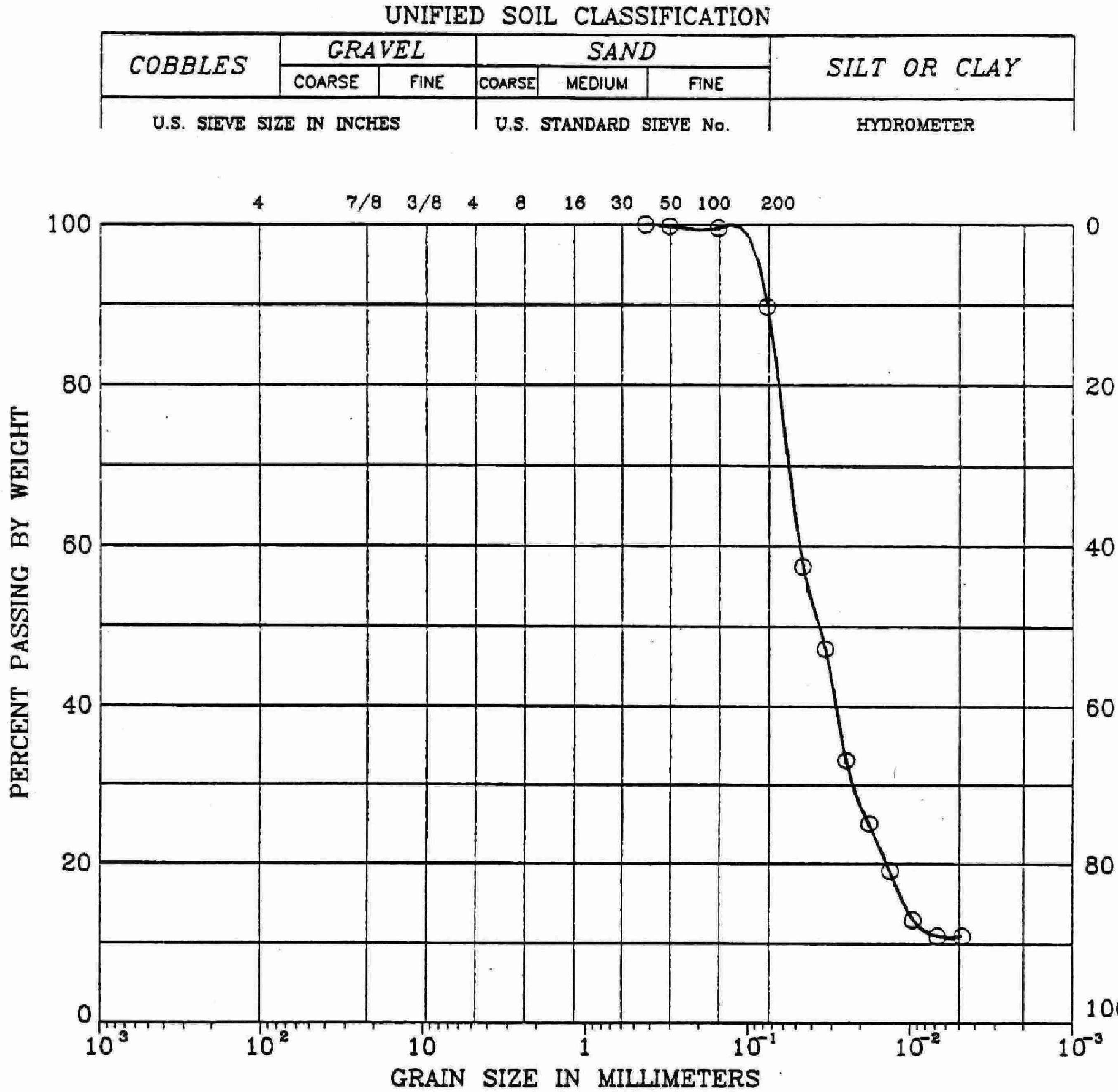
Project No. TA8879	TERRAQUA INVESTIGATIONS
ENE	GRAIN SIZE DISTRIBUTION Figure No. 2



SYMBOL	BORING	DEPTH (m)	LL (%)	PI (%)	DESCRIPTION
O	OW2	10.7			SAND/SILT, SOME GRAVEL

Remark :

Project No. TA8879	TERRAQUA INVESTIGATIONS
ENE	GRAIN SIZE DISTRIBUTION Figure No. 3



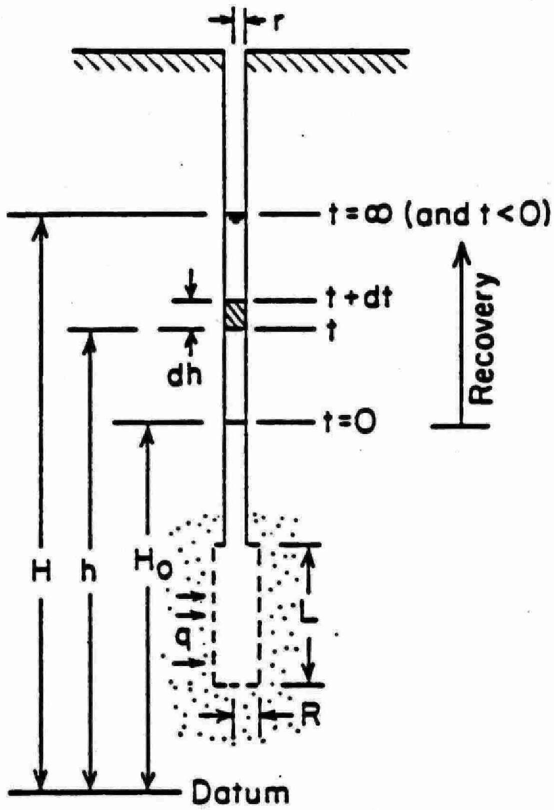
SYMBOL	BORING	DEPTH (m)	LL (%)	PI (%)	DESCRIPTION
O	OW4	3.2			SILT, SOME SAND

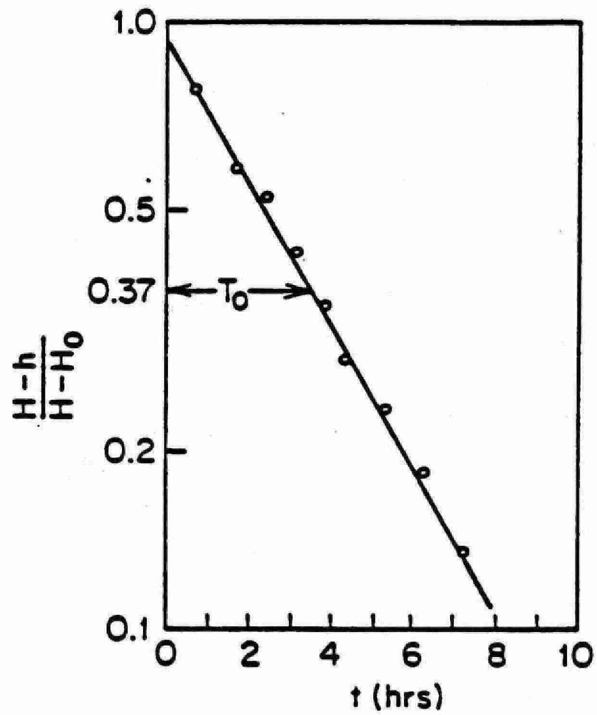
Remark :

Project No. TA8879	TERRAQUA INVESTIGATIONS
ENE	GRAIN SIZE DISTRIBUTION Figure No. 4

APPENDIX B

EXAMPLE CALCULATION FOR SLUG TEST ANALYSIS





(Freeze and Cherry, 1979)

$$K = \frac{r^2 \ln(L/R)}{2\ L\ T_o}$$

where K= hydraulic conductivity
r= radius of piezometer
R= radius of sand pack
L= screen length

CALCULATION OF HYDRAULIC GRADIENTS

W.L. @ OW3 - 93.9 m (Aug. 18/88)
W.L. @ OW6 - 92.41 m (Aug. 18/88)

Distance between monitors - 150 m

$$\text{Horizontal Gradient} = \frac{93.9-92.41}{150} = 0.01 \text{ m/m}$$

SLUG TEST DATA

Project name	Norwich Landfill
Project number	TA8879
Monitor ID	OW1-D
Static water level (mBTOP)	6.66
Initial water level (mBTOP)	9.17
Screen length (m)	1.32
Screen radius (m)	0.1016
Piezometer radius (m)	0.0254

	TIME (yy/mm/dd)	DATE (hh:mm:ss)	ELAPSED TIME (seconds)	DEPTH TO WATER (m)	H/Ho
1	88/ 7/11	15:53:30	0	9.17	1.000
2	88/ 7/11	15:54: 0	30	9.07	0.960
3	88/ 7/11	15:55: 0	90	8.84	0.869
4	88/ 7/11	15:57: 0	210	8.47	0.721
5	88/ 7/11	16: 0: 0	390	8.00	0.534
6	88/ 7/11	16:10: 0	990	7.10	0.175
7	88/ 7/11	16:20: 0	1590	6.71	0.022
8	88/ 7/11	16:25: 0	1890	6.62	
9	88/ 7/11	16:30: 0	2190	6.56	

SLUG TEST DATA

Project name	Norwich Landfill
Project number	TA8879
Monitor ID	OW1-D
Static water level (mBTOP)	5.88
Initial water level (mBTOP)	9.01
Screen length (m)	1.32
Screen radius (m)	0.1016
Piezometer radius (m)	0.0254

	TIME (yy/mm/dd)	DATE (hh:mm:ss)	ELAPSED TIME (seconds)	DEPTH TO WATER (m)	H/Ho
1	88/ 8/18	14:58: 0	0	9.01	1.000
2	88/ 8/18	14:58:30	30	8.86	0.952
3	88/ 8/18	14:59: 0	60	8.71	0.904
4	88/ 8/18	15: 0: 0	120	8.44	0.818
5	88/ 8/18	15: 1: 0	180	8.19	0.738
6	88/ 8/18	15: 2: 0	240	7.97	0.668
7	88/ 8/18	15: 3: 0	300	7.78	0.607
8	88/ 8/18	15: 8: 0	600	7.02	0.364
9	88/ 8/18	15:13: 0	900	6.57	0.220
10	88/ 8/18	15:41: 0	2580	5.92	0.013

SLUG TEST DATA

Project name	Norwich Landfill
Project number	TA8879
Monitor ID	OW2-D
Static water level (mBTOP)	3.2
Initial water level (mBTOP)	9.99
Screen length (m)	2.36
Screen radius (m)	0.1016
Piezometer radius (m)	0.0254

	TIME (yy/mm/dd)	DATE (hh:mm:ss)	ELAPSED TIME (seconds)	DEPTH TO WATER (m)	H/Ho
1	88/ 7/11	14:53:30	0	9.99	1.000
2	88/ 7/11	14:54:30	60	9.92	0.990
3	88/ 7/11	14:56: 0	150	9.81	0.973
4	88/ 7/11	15: 0: 0	390	9.54	0.934
5	88/ 7/11	15:21: 0	1650	8.32	0.755
6	88/ 7/11	15:45: 0	3090	7.22	0.593
7	88/ 7/11	16:15: 0	4890	6.17	0.438
8	88/ 7/11	17: 0: 0	7590	5.09	0.278

SLUG TEST DATA

Project name	Norwich Landfill
Project number	TA8879
Monitor ID	OW2-D
Static water level (mBTOP)	2.41
Initial water level (mBTOP)	9.15
Screen length (m)	2.36
Screen radius (m)	0.1016
Piezometer radius (m)	0.0254

	TIME (yy/mm/dd)	DATE (hh:mm:ss)	ELAPSED TIME (seconds)	DEPTH TO WATER (m)	H/Ho
1	88/ 8/18	15:34: 0	0	9.15	1.000
2	88/ 8/18	15:34:30	30	9.10	0.993
3	88/ 8/18	15:35: 0	60	9.07	0.988
4	88/ 8/18	15:36: 0	120	8.99	0.976
5	88/ 8/18	15:37: 0	180	8.92	0.966
6	88/ 8/18	15:45: 0	660	8.37	0.884
7	88/ 8/18	16: 6: 0	1920	7.15	0.703
8	88/ 8/18	16:26: 0	3120	6.22	0.565
9	88/ 8/18	16:59: 0	5100	5.10	0.399
10	88/ 8/18	17:36: 0	7320	4.24	0.272

SLUG TEST DATA

Project name	Norwich Landfill
Project number	TA8879
Monitor ID	OW3
Static water level (mBTOP)	2.32
Initial water level (mBTOP)	4.01
Screen length (m)	2
Screen radius (m)	0.102
Piezometer radius (m)	0.0254

	TIME (yy/mm/dd)	DATE (hh:mm:ss)	ELAPSED TIME (seconds)	DEPTH TO WATER (m)	H/Ho
1	88/ 8/18	15:58: 0	0	4.01	1.000
2	88/ 8/18	15:59: 0	60	3.97	0.976
3	88/ 8/18	16: 0: 0	120	3.94	0.959
4	88/ 8/18	16: 1: 0	180	3.92	0.947
5	88/ 8/18	16: 2: 0	240	3.91	0.941
6	88/ 8/18	16:18: 0	1200	3.67	0.799
7	88/ 8/18	16:56: 0	3480	3.31	0.586
8	88/ 8/18	17:33: 0	5700	2.95	0.373

SLUG TEST DATA

Project name	Norwich Landfill
Project number	TA8879
Monitor ID	OW2-S
Static water level (mBTOP)	3.145
Initial water level (mBTOP)	4.54
Screen length (m)	2.44
Screen radius (m)	0.1016
Piezometer radius (m)	0.0254

	TIME (yy/mm/dd)	DATE (hh:mm:ss)	ELAPSED TIME (seconds)	DEPTH TO WATER (m)	H/Ho
1	88/ 7/11	14:37:50	0	4.54	1.000
2	88/ 7/11	14:38: 0	10	4.50	0.971
3	88/ 7/11	14:38:20	30	4.45	0.935
4	88/ 7/11	14:38:32	42	4.40	0.900
5	88/ 7/11	14:38:45	55	4.35	0.864
6	88/ 7/11	14:39: 0	70	4.30	0.828
7	88/ 7/11	14:40: 0	130	4.05	0.649
8	88/ 7/11	14:41: 6	196	4.00	0.613
9	88/ 7/11	14:42: 0	250	3.90	0.541
10	88/ 7/11	14:43:57	367	3.70	0.398
11	88/ 7/11	14:46:38	528	3.50	0.254
12	88/ 7/11	14:51:34	824	3.30	0.111

SLUG TEST DATA

Project name	Norwich Landfill
Project number	TA8879
Monitor ID	OW5
Static water level (mBTOP)	8.24
Initial water level (mBTOP)	8.38
Screen length (m)	2.48
Screen radius (m)	0.1016
Piezometer radius (m)	0.0254

	TIME (yy/mm/dd)	DATE (hh:mm:ss)	ELAPSED TIME (seconds)	DEPTH TO WATER (m)	H/Ho
1	88/ 7/11	14: 8: 0	0	8.38	1.000
2	88/ 7/11	14: 8:27	27	8.35	0.786
3	88/ 7/11	14: 8:41	41	8.30	0.429
4	88/ 7/11	14: 9: 0	60	8.28	0.286
5	88/ 7/11	14: 9:30	90	8.26	0.143

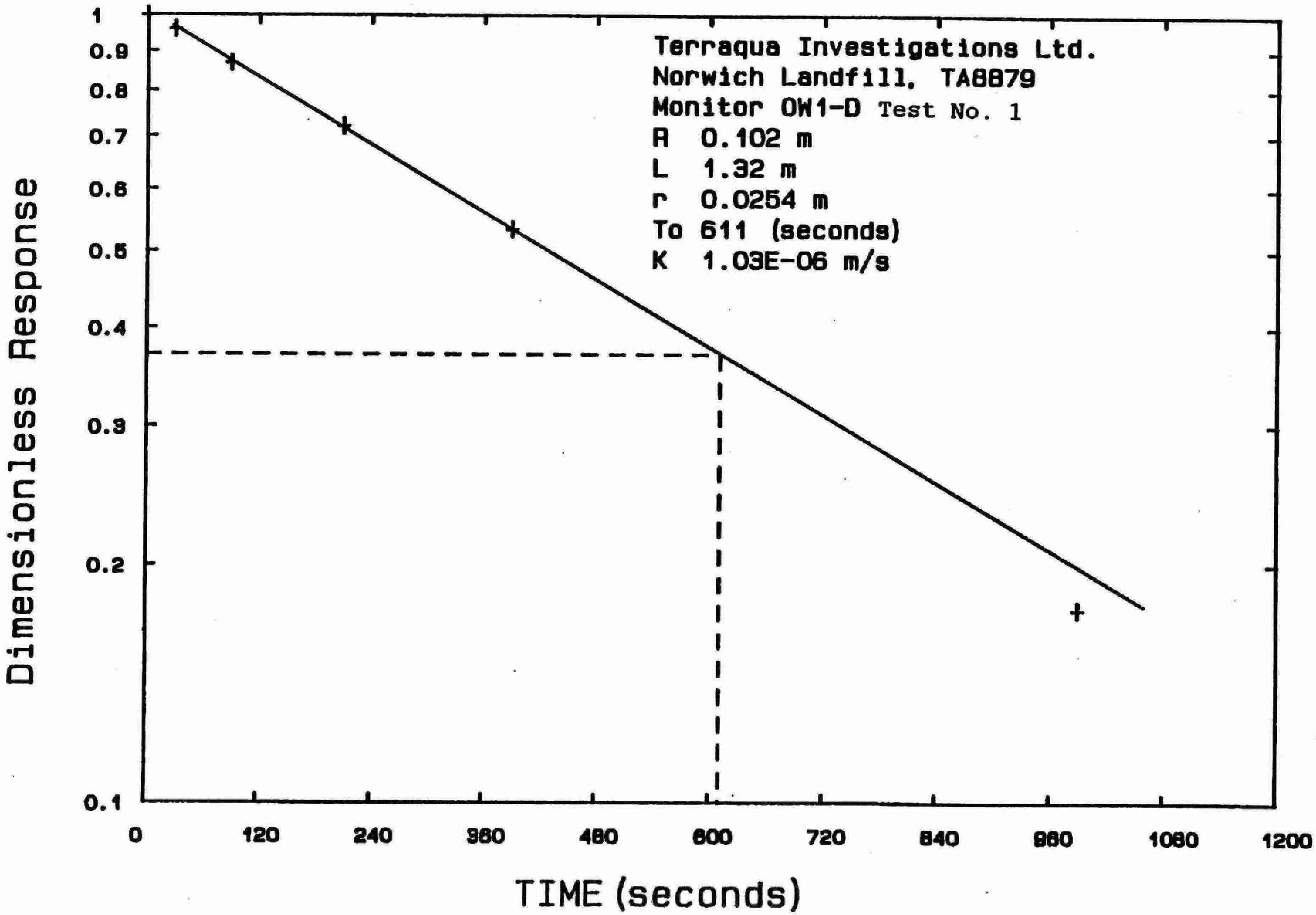
SLUG TEST DATA

Project name	Norwich Landfill
Project number	TA8879
Monitor ID	OW7-D
Static water level (mBTOP)	6.75
Initial water level (mBTOP)	8.91
Screen length (m)	1.07
Screen radius (m)	0.1016
Piezometer radius (m)	0.0254

	TIME (yy/mm/dd)	DATE (hh:mm:ss)	ELAPSED TIME (seconds)	DEPTH TO WATER (m)	H/Ho
1	88/ 7/11	15:27: 0	0	8.91	1.000
2	88/ 7/11	15:28: 0	60	8.69	0.898
3	88/ 7/11	15:30: 0	180	8.30	0.718
4	88/ 7/11	15:39: 0	720	7.26	0.236
5	88/ 7/11	15:50: 0	1380	6.84	0.044

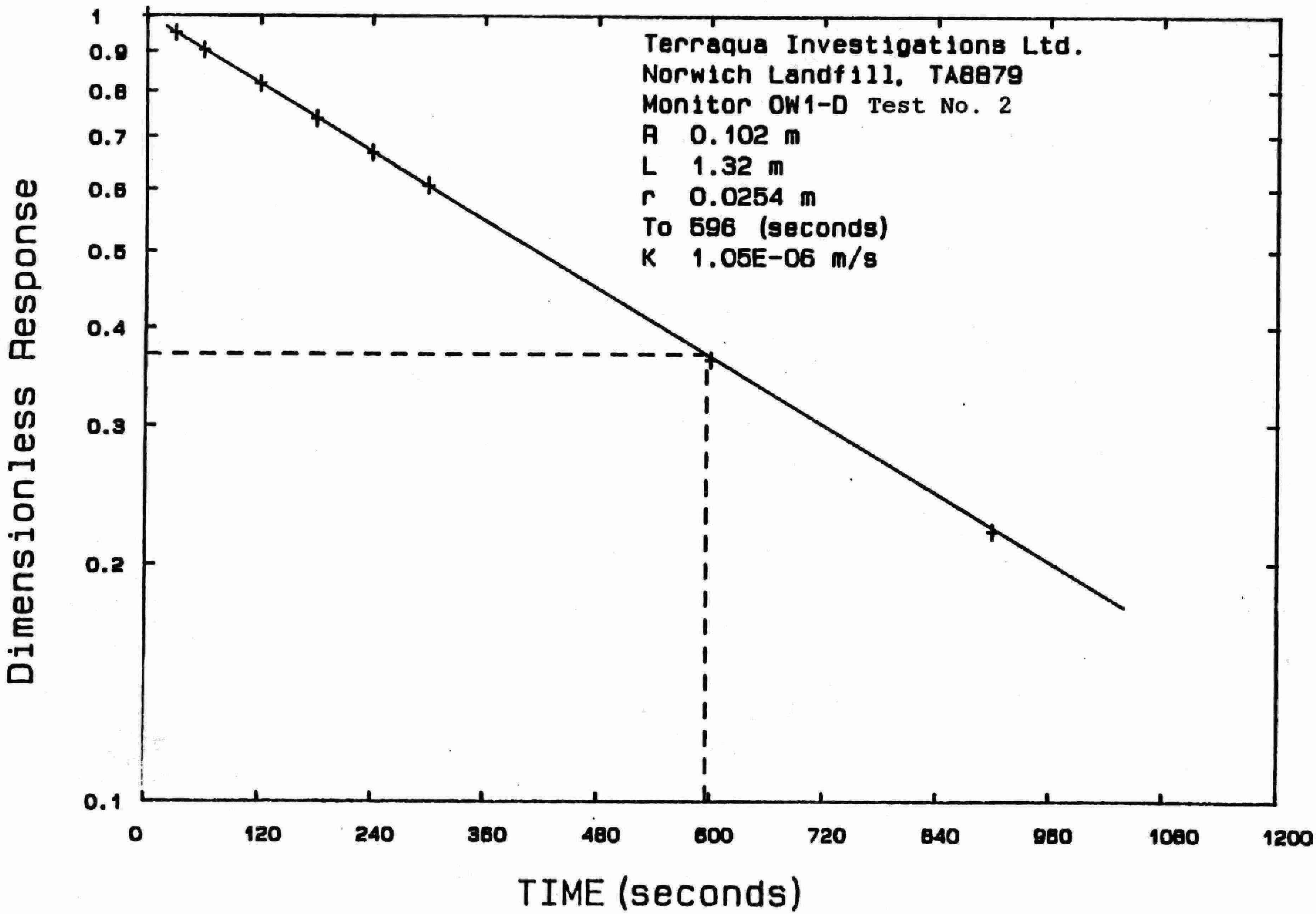
SLUG TEST ANALYSIS

FIGURE B-1a



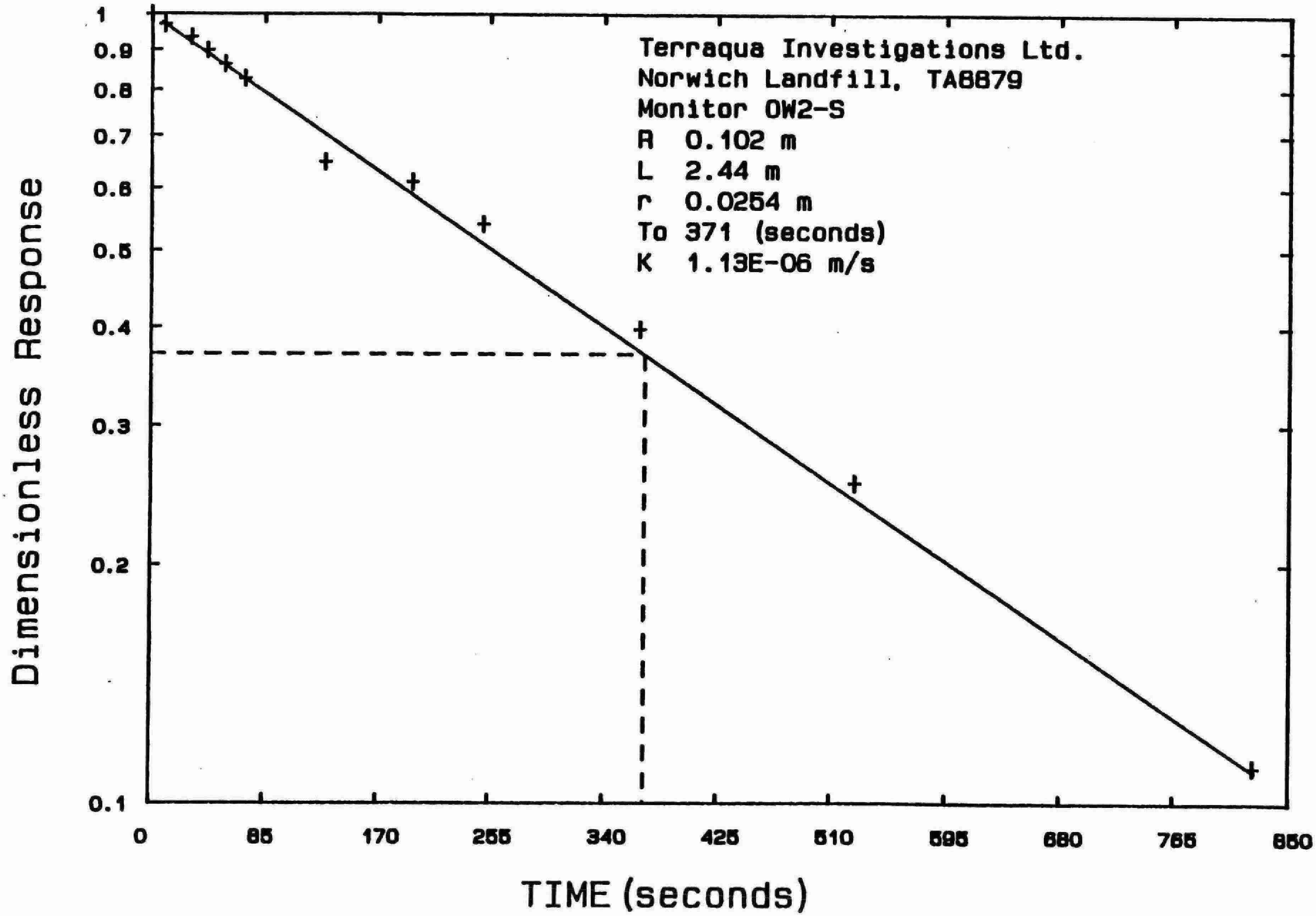
SLUG TEST ANALYSIS

FIGURE B-1b



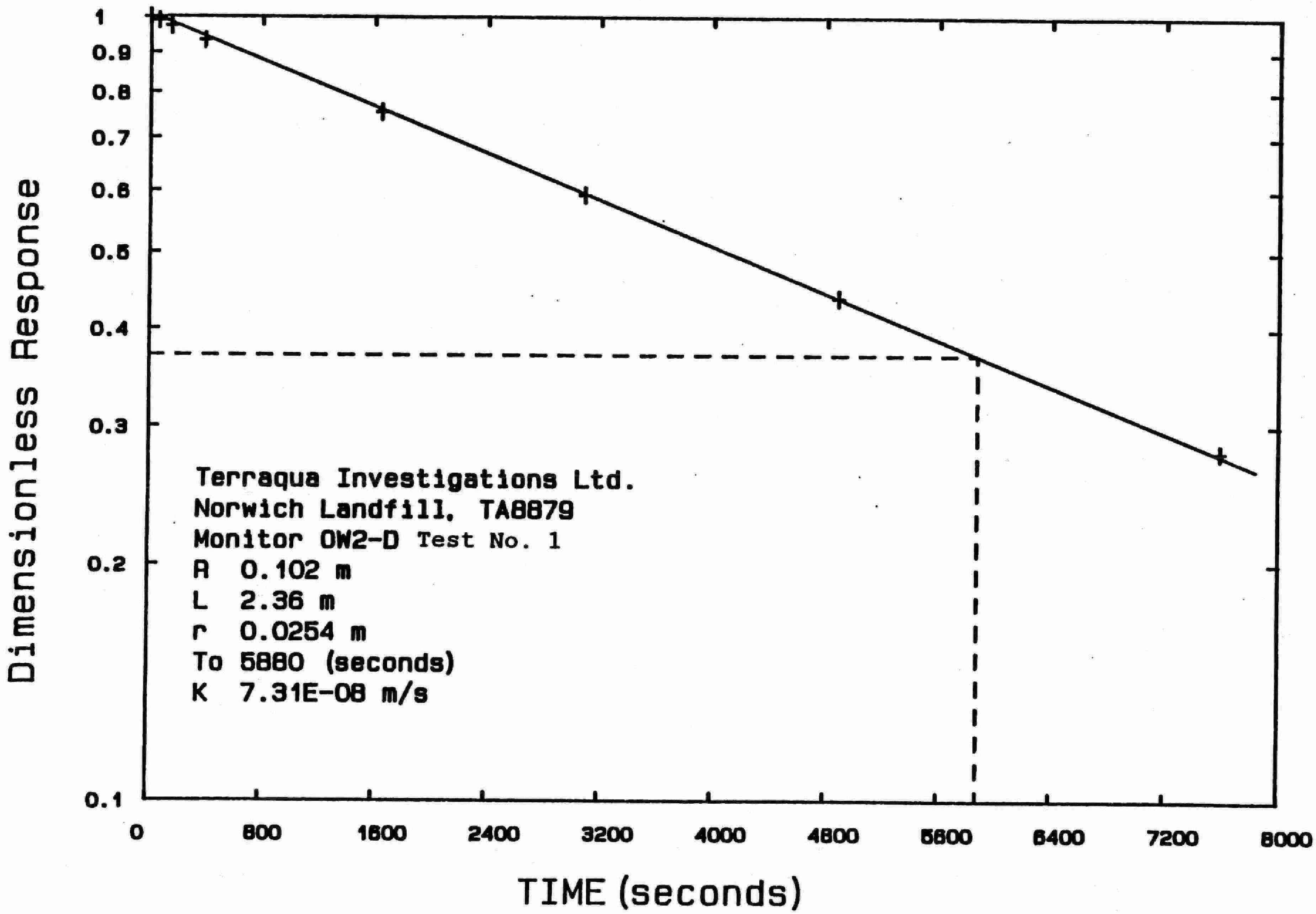
SLUG TEST ANALYSIS

FIGURE B-2



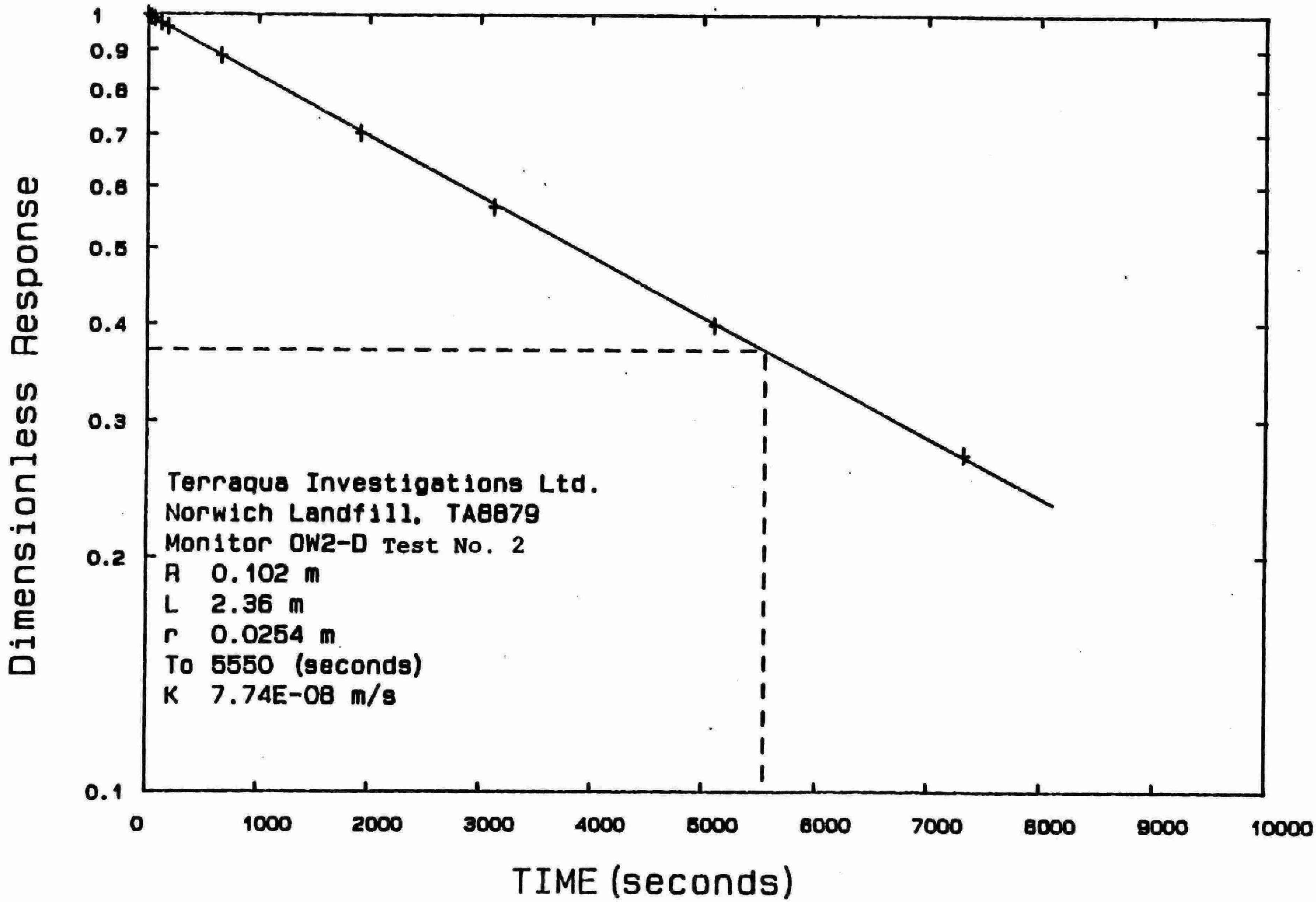
SLUG TEST ANALYSIS

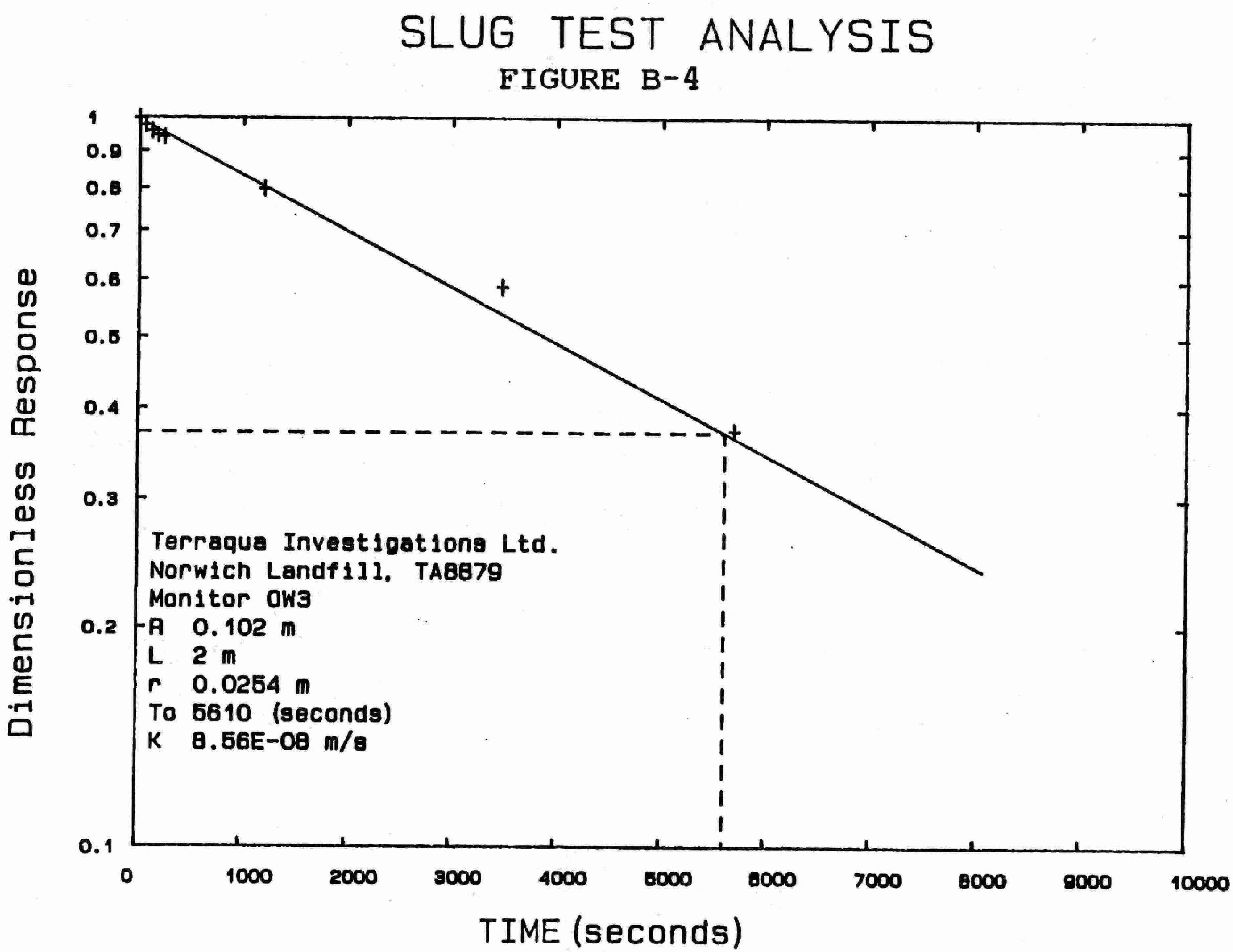
FIGURE B-3a



SLUG TEST ANALYSIS

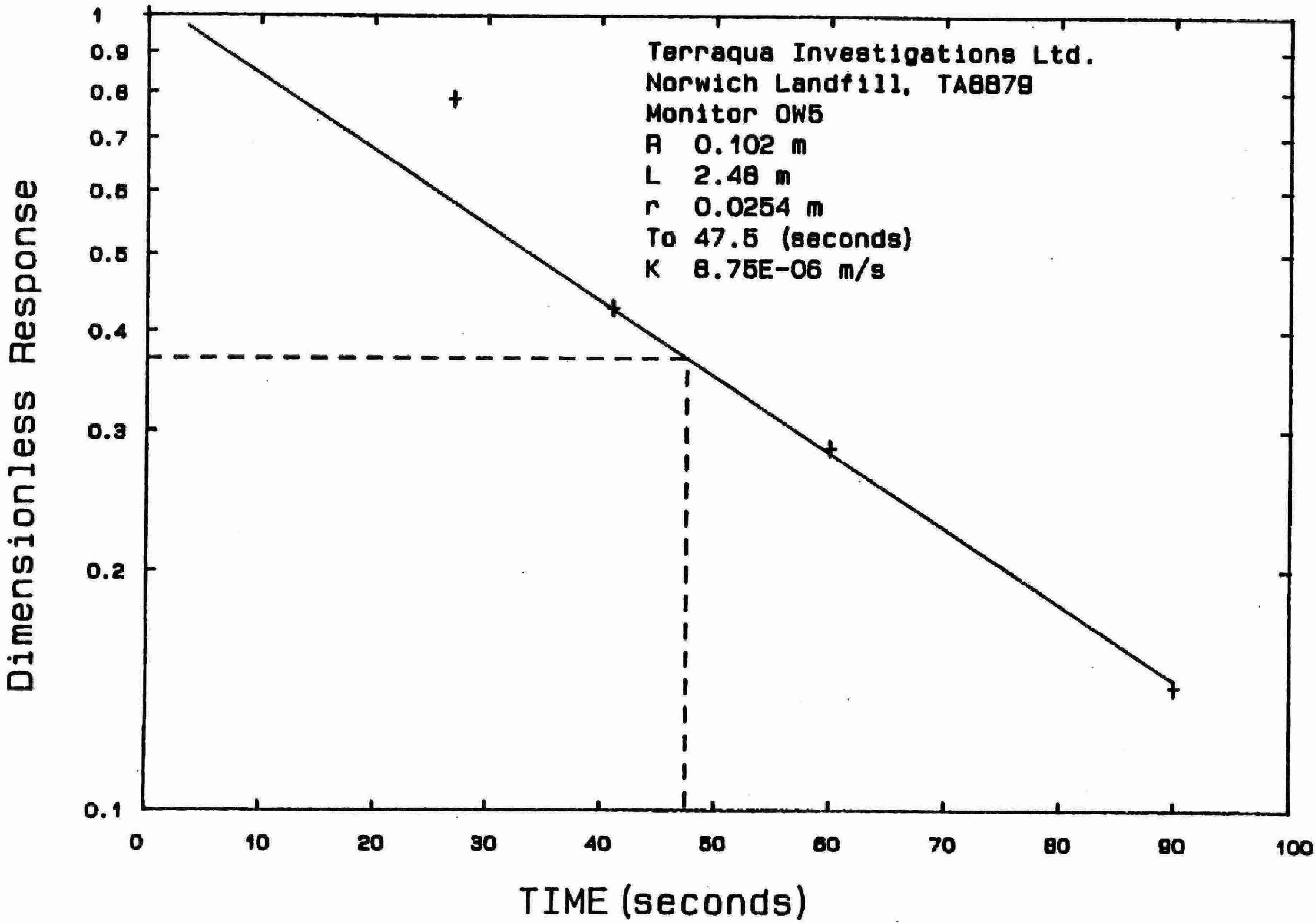
FIGURE B-3b




SLUG TEST ANALYSIS
FIGURE B-4
Dimensionless Response
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
TIME (seconds)
Terraqua Investigations Ltd.
Norwich Landfill, TA6879
Monitor OW3
R 0.102 m
L 2 m
r 0.0254 m
To 5610 (seconds)
K 8.56E-08 m/s

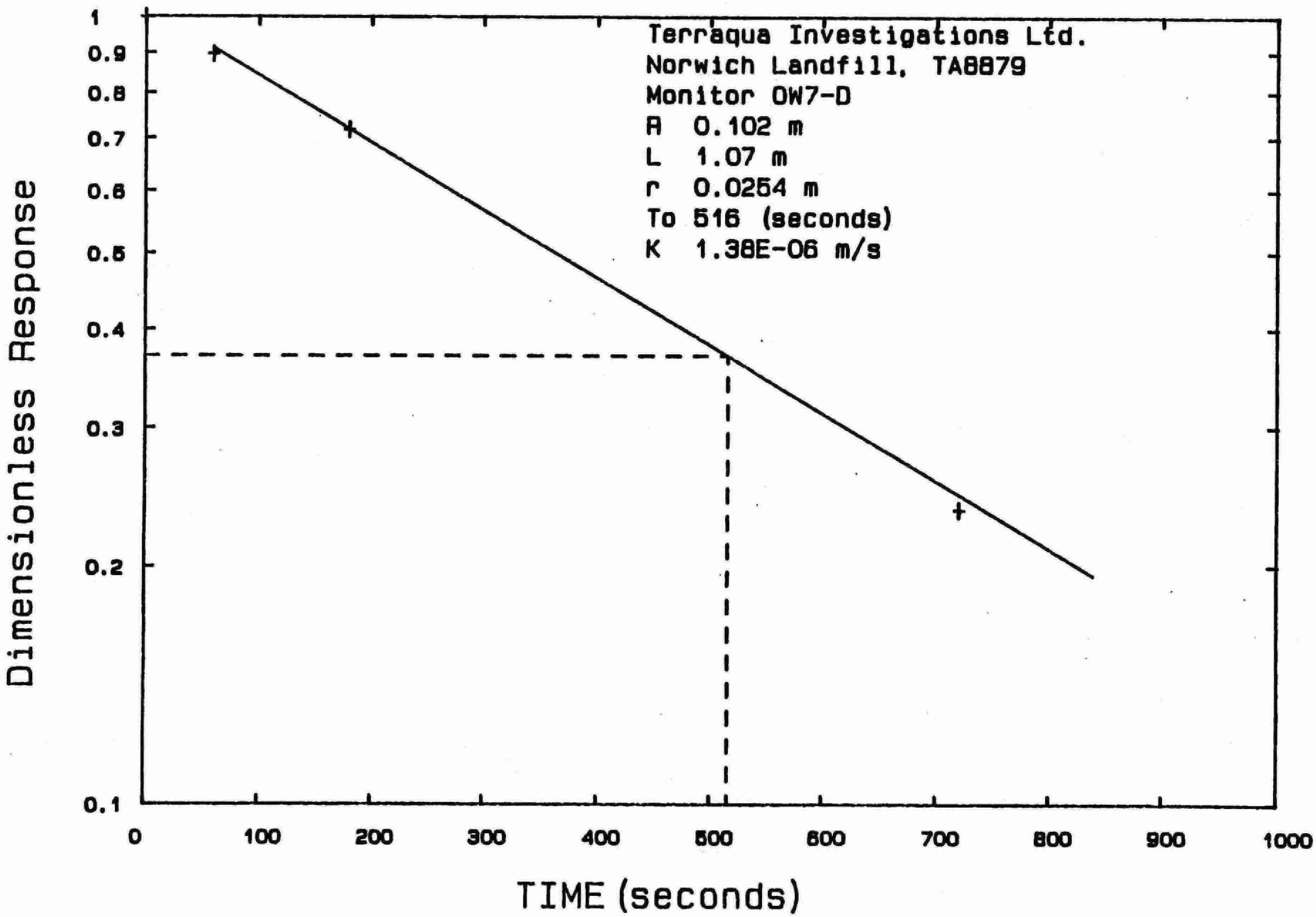
SLUG TEST ANALYSIS

FIGURE B-5



SLUG TEST ANALYSIS

FIGURE B-6



APPENDIX C

IDENTIFICATION NO.		LAB BLANK	1517-01	% RECOVERY SPIKE	MDL
NO	COMPOUND	ppb	ppb		ppb
1	n-Nitrosodimethylamine	<	<	0 *	0.8
2	bis(2-chloroethyl)ether	<	<	111	0.4
3	1,3-Dichlorobenzene	<	<	41	0.2
4	1,4-Dichlorobenzene	<	<	38	0.2
5	bis(2-chloroisopropyl)ether	<	<	110	0.8
6	1,2-Dichlorobenzene	<	<	44	0.2
7	Phenol	<	<	64	0.5
8	n-Nitrosodi-n-propylamine	<	<	103	0.6
9	Hexachloroethane	<	<	37	0.6
10	Nitrobenzene	<	<	162	0.2
11	Isophorone	<	<	109	0.4
12	bis(2-chlorethoxy)methane	<	<	143	0.9
13	1,2,4-Trichlorobenzene	<	<	52	0.2
14	Naphthalene	<	<	72	0.1
15	2-Chlorophenol	<	<	66	0.4
16	Hexachlorobutadiene	<	<	28	0.8
17	2,4-Dimethylphenol	<	<	117	0.5
18	Hexachlorocyclopentadiene	<	<	0 *	0.7
19	p-Chloro-m-cresol	<	<	67	0.3
20	2,4-Dichlorophenol	<	<	63	0.3
21	2-Chloronaphthalene	<	<	68	0.3
22	2-nitrophenol	<	<	164	0.9
23	Dimethylphthalate	<	<	57	0.1
24	2,4,6-Trichlorophenol	<	<	55	0.1
25	Acenaphthylene	<	<	81	0.1
26	2,4-Dinitrophenol	<	<	13	5.0
27	2,6-Dinitrotoluene	<	<	64	0.6

* Spiked at less than MDL

RESULTS OF BASE NEUTRAL/ACID EXTRACTABLES

IDENTIFICATION NO.		LAB BLANK	1517-01	% RECOVERY SPIKE	MDL
NO	COMPOUND	ppb	ppb	ppb	ppb
28	4-Nitrophenol	<	<	57	0.8
29	Acenaphthene	<	<	80	0.1
30	2,4-Dintrotoluene	<	<	120	0.5
31	Diethyl phthalate	<	<	112	0.1
32	Fluorene	<	<	94	0.1
33	4-Chlorophenylphenyl ether	<	<	88	0.4
34	Total diphenylamine **	<	<	118	0.9
35	4,6-Dinitro-o-cresol	<	<	0 *	5.0
36	1,2-Diphenyl hydrazine	<	<	204	0.5
37	4-Bromophenylphenyl ether	<	<	100	0.3
38	Hexachlorobenzene	<	<	105	0.4
39	Phenanthrene	<	<	99	0.1
40	Anthracene	<	<	91	0.1
41	Pentachlorophenol	<	<	59	0.3
42	Di-n-butyl phthalate	0.4	0.3	118	0.1
43	Fluoranthene	<	<	114	0.1
44	Benzidine	<	<	0 *	5.0
45	Pyrene	<	<	114	0.1
46	Butylbenzyl phthalate	<	16.7	97	0.2
47	Benzo(a)anthracene	<	<	113	0.2
48	Chrysene	<	<	112	0.2
49	3,3-Dichlorobenzidine	<	<	0 *	5.0
50	bis(2-ethylhexyl)phthalate	1.8	6.1	133	0.1
51	Di-n-octyl phthalate	<	0.9	106	0.1
52	Benzo(b)fluoranthene	<	<	108	0.2
53	Benzo(k)fluoranthene	<	<	113	0.2
54	Benzo(a)pyrene	<	<	104	0.1
55	Indeno(123-cd)pyrene	<	<	113	0.4
56	Dibenzo(a,h)anthracene	<	<	119	0.4
57	Benzo(g,h,i)perylene	<	<	116	0.3

* Spiked at level lower than MDL
** diphenylamine + n-Nitrosodiphenylamine

RESULTS OF BASE NEUTRAL/ACID EXTRACTABLES (cont)

IDENTIFICATION NO.		LAB BLANK	1517-01	% RECOVERY SPIKE	MDL
NO	COMPOUND	ppb	ppb		ppb
58	Camphene	<	<	62	1.0
59	o-Cresol	<	<	112	1.0
60	m-Cresol	<	<	94	1.0
61	p-Cresol	<	1.0	67	1.0
62	Indole	<	<	110	1.0
63	1-Methylnaphthalene	<	<	94	1.0
64	1-Chloronaphthalene	<	<	117	1.0
65	Phenyl ether	<	<	109	1.0
66	2,3,5-Trichlorophenol	<	<	55	1.0
67	2,4,5-Trichlorophenol	<	<	57	1.0
68	2,3,4-Trichlorophenol	<	<	59	1.0
69	2,3,5,6-Tetrachlorophenol	<	<	56	1.0
70	2,3,4,6-Tetrachlorophenol	<	<	57	1.0
71	2,3,4,5-Tetrachlorophenol	<	<	52	1.0
72	Perylene	<	<	49	1.0
73	5-Nitroacenaphthene	<	<	139	1.0
74	2,6-Dichlorophenol	<	<	133	1.0
% RECOVERY OF SURROGATES					
2-Fluorophenol		40	45	34	
d8-Naphthalene		70	47	86	
d12-Chrysene		98	105	111	

RESULTS OF BASE NEUTRAL/ACID EXTRACTABLES (cont)

IDENTIFICATION NO.		LAB BLANK	1517-01	MDL
NO	COMPOUND	ppb	ppb	ppb
1	Chloromethane	<	<	3.8
2	Vinyl chloride	<	<	5.0
3	Bromomethane	<	<	2.0
4	Chloroethane	<	<	1.8
5	Trichlorofluoromethane	<	<	3.5
6	Acrolein	4.2	<	2.2
7	1,1-Dichloroethylene	<	<	1.6
8	Methylene Chloride	4.8	3.5	1.8
9	Acrylonitrile	<	<	2.1
10	trans-1,2-Dichloroethylene	<	<	0.7
11	1,1-Dichloroethane	<	<	0.5
12	Methyl ethyl ketone	<	<	1.1
13	Chloroform	<	<	0.4
14	Bromochloromethane	<	<	0.2
15	1,1,1-Trichloroethane	<	<	0.5
16	Carbon tetrachloride	<	<	0.7
17	1,2-Dichloroethane	<	<	0.3
18	Benzene	<	<	0.4
19	Trichloroethylene	<	<	1.9
20	1,2-Dichloropropane	<	<	0.2
21	Bromodichloromethane	<	<	0.2
22	2-Chloroethylvinyl ether	<	<	0.4
23	trans-1,3-Dichloropropylene	<	<	0.3
24	cis-1,3-Dichloropropylene	<	<	0.5
25	Toluene	3.0	4.3	0.7
26	1,1,2-Trichloroethane	<	<	0.3
27	Tetrachloroethylene	<	<	0.8
28	Dibromochloromethane	<	<	0.2
29	Ethylene dibromide	<	<	0.6
30	Chlorobenzene	<	<	0.2
31	m & p Xylene	<	<	0.6
32	Ethyl benzene	<	<	2.6
33	Styrene	<	<	0.4
34	o-Xylene	<	<	0.4
35	Bromoform	<	<	0.3
36	1,1,2,2-Tetrachloroethane	<	<	0.5
37	1,3-Dichlorobenzene	<	<	0.2
38	1,4-Dichlorobenzene	<	<	0.1
39	1,2-Dichlorobenzene	<	<	0.4
% RECOVERY OF SURROGATES				
d5-Bromethane		94	106	
d4-1,2-Dichloroethane		69	103	
d8-Toluene		63	124	
4-Bromofluorobenzene		72	142	

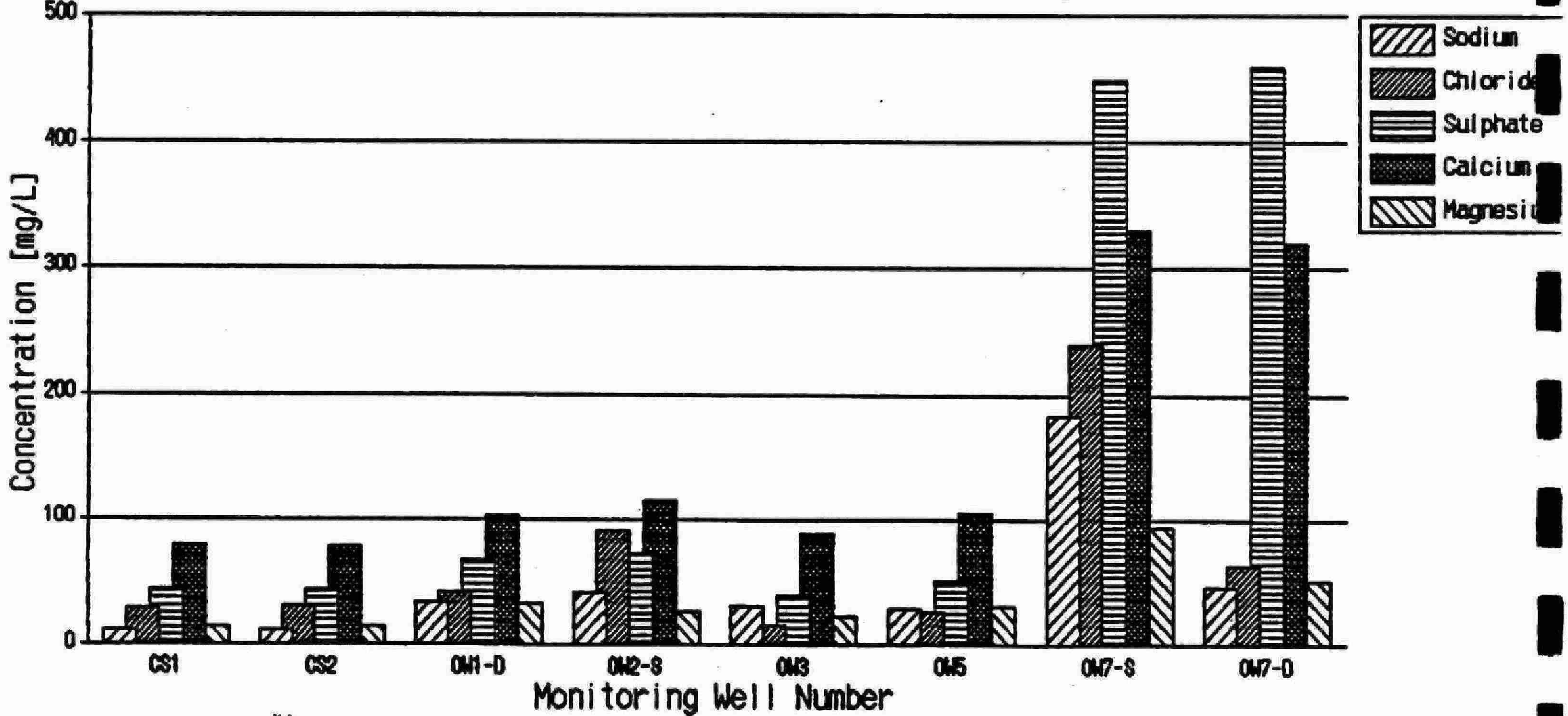
RESULTS OF VOLATILE ORGANIC COMPOUNDS

IDENTIFICATION		LAB BLANK	1517-01	% RECOVERY SPIKE	MDL
NO.	COMPOUND	ppb	ppb		ppb
1	alpha-BHC	<	<	77	0.1
2	beta-BHC	<	<	75	0.1
3	gamma-BHC	<	<	72	0.1
4	delta-BHC	<	<	100	0.1
5	Heptachlor	<	<	79	0.1
6	Aldrin	<	<	62	0.1
7	Heptachlor epoxide	<	<	64	0.1
8	alpha-Endosulfan	<	<	62	0.1
9	pp-DDE	<	<	56	0.2
10	Dieldrin	<	<	70	0.2
11	Endrin	<	<	108	0.2
12	beta-Endosulfan	<	<	74	0.2
13	pp-DDD	<	<	62	0.2
14	Endrin aldehyde	<	<	44	0.2
15	pp-DDT	<	<	47	0.2
16	Endosulfan sulfate	<	<	94	0.2
17	Chlordane	<	<	NS	1.0
18	Toxaphene	<	<	NS	2.0
19	PCB - 1242	<	0.02	NS	0.5
20	PCB - 1254	<	0.09	NS	0.8
21	PCB - 1221	<	<	NS	0.5
22	PCB - 1232	<	<	NS	0.5
23	PCB - 1248	<	<	NS	0.5
24	PCB - 1260	<	0.06	NS	0.8
25	PCB - 1016	<	<	NS	0.5

NS = Not in Spiking Mixture

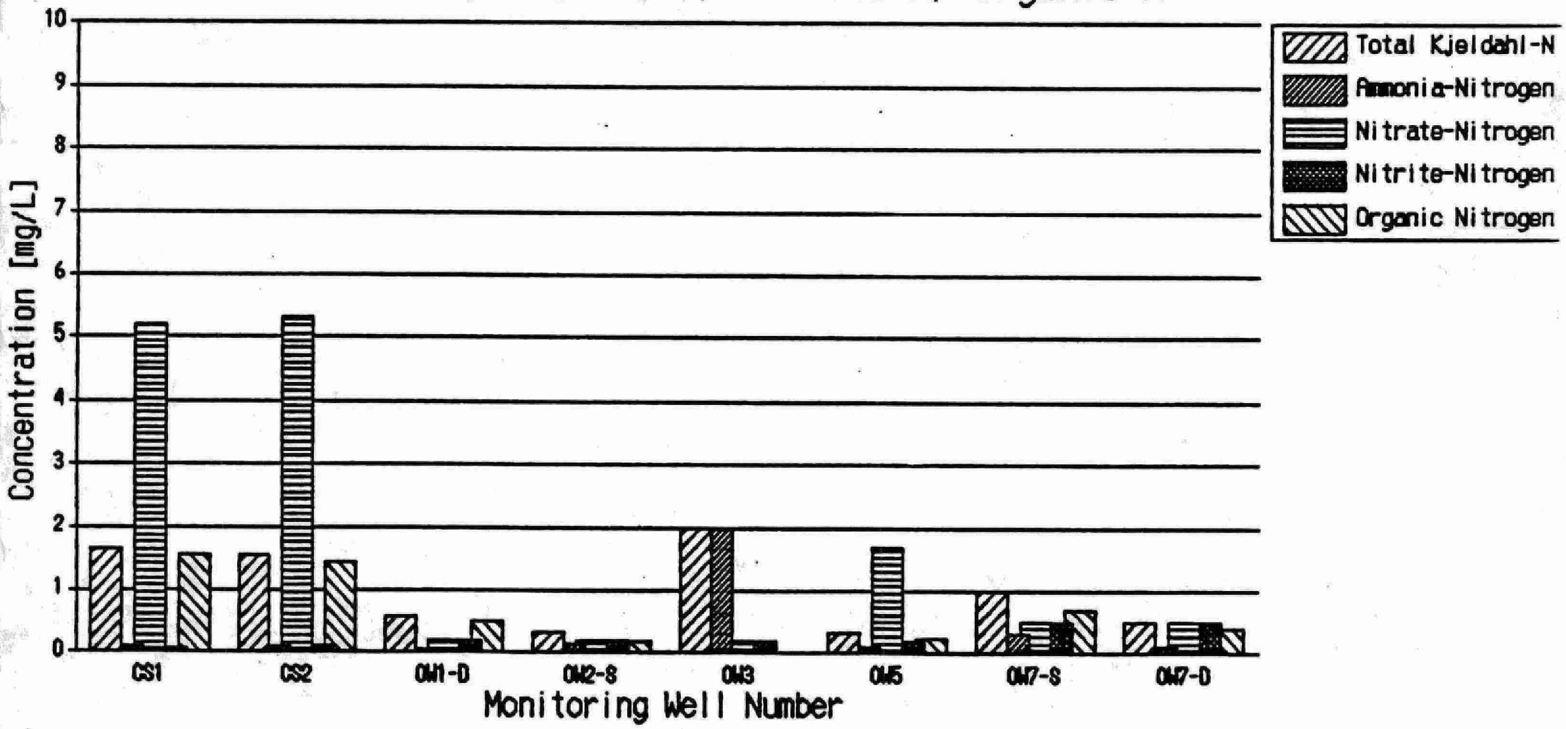
RESULTS OF PESTICIDES & PCB'S

Figure C-1 Results of Water Quality Analysis
Norwich Landfill TA8879
Sodium, Chloride, Sulphate, Calcium, Magnesium



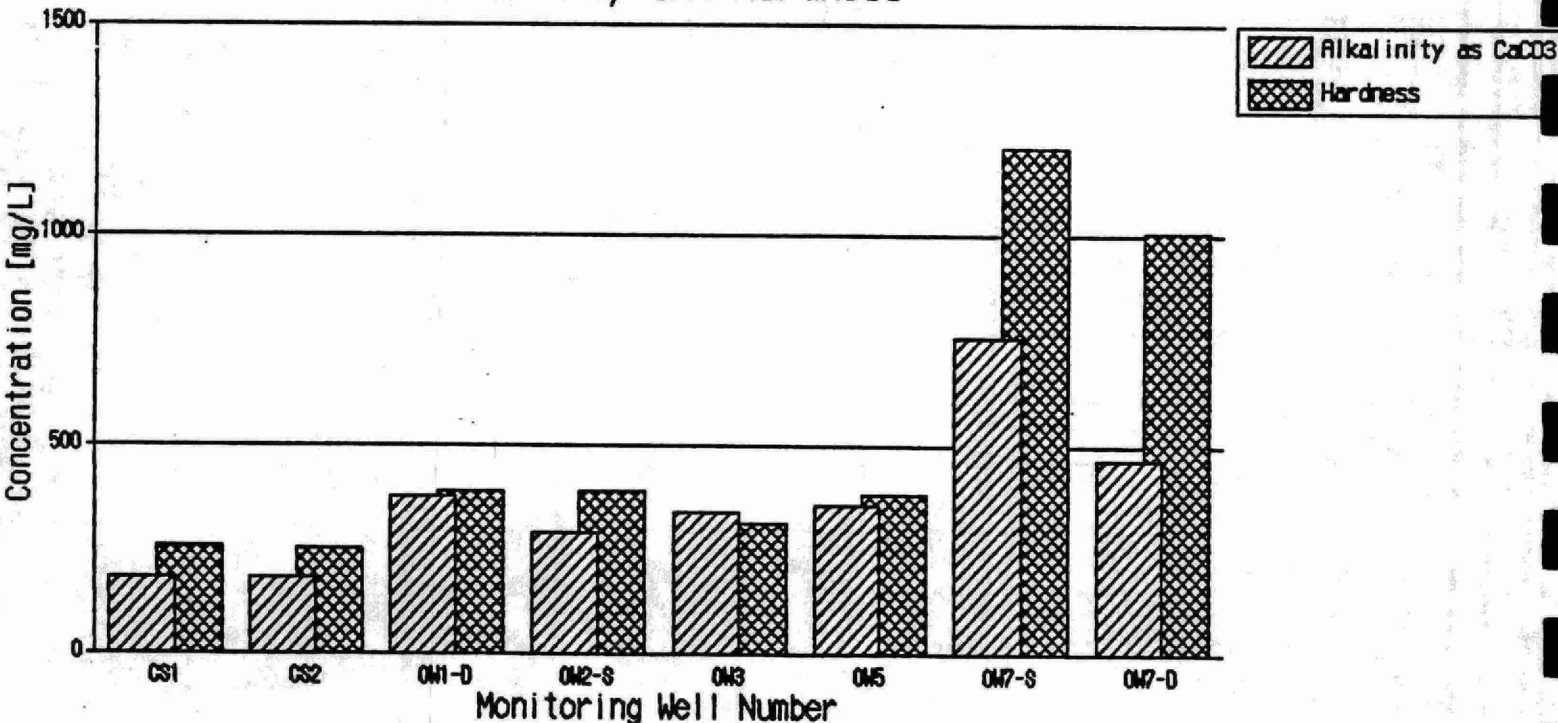
SL Sodium	20	mg/L
MDC Chloride	250	mg/L
MDC Sulphate	500	mg/L

Figure C-2 Results of Water Quality Analysis
Norwich Landfill TA8879
TKN, Ammonia-N, Nitrate-N, Nitrite-N, Organic-N



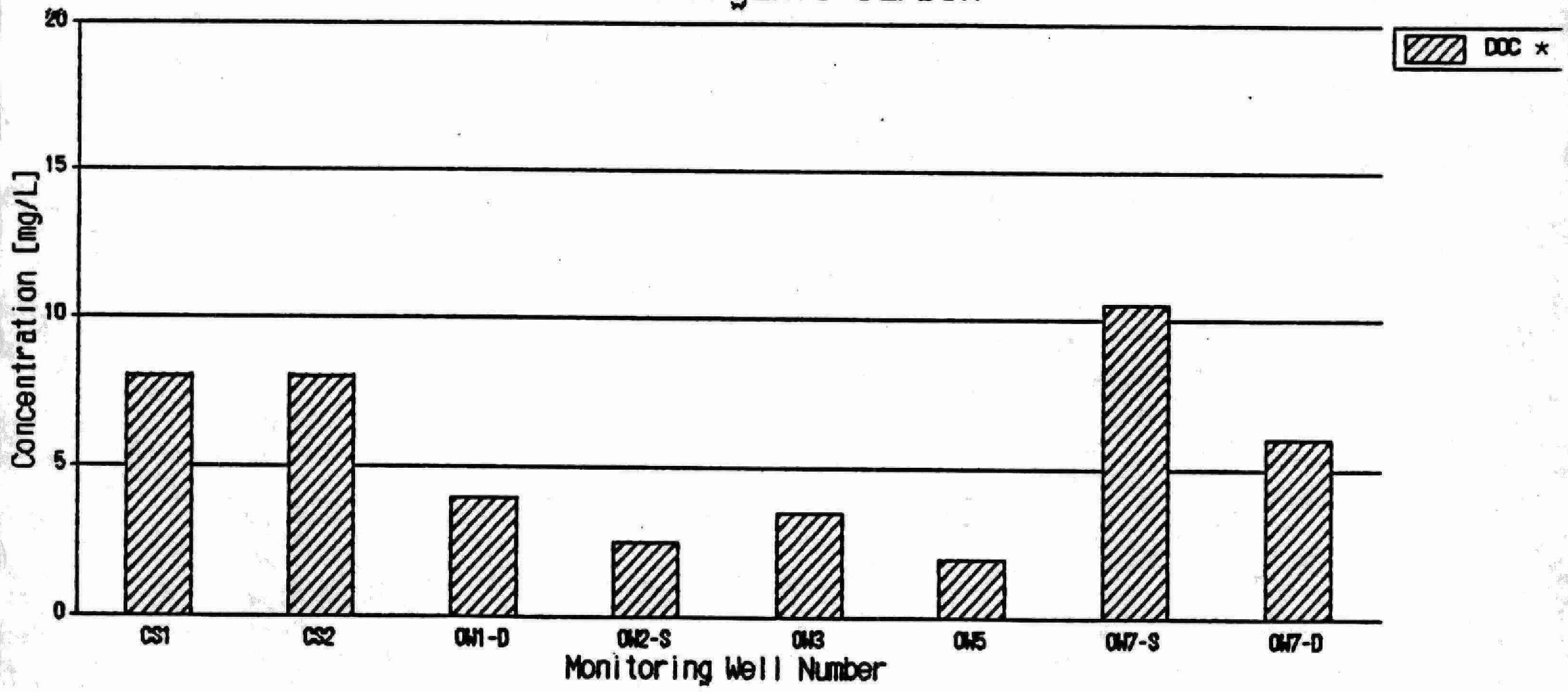
MDC Organic Nitrogen	0.15	mg/L
MAC Nitrate Nitrogen	10	mg/L
MAC Nitrite Nitrogen	1	mg/L

Figure C-3 Results of Water Quality Analysis
Norwich Landfill TA8879
Alkalinity and Hardness



SL Hardness 500 mg/L
SL Alkalinity 500 mg/L

Figure C-4 Results of Water Quality Analysis
Norwich Landfill TA8879
Dissolved Organic Carbon



* Dissolved Organic Carbon

MDC of TOC 5.0 mg/L